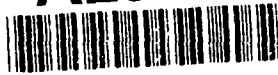


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# NAVAL POSTGRADUATE SCHOOL Monterey, California



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UPGRADE AND EXTENSION OF THE  
DATA ACQUISITION SYSTEM FOR  
PROPULSION AND GAS DYNAMIC LABORATORIES

by

Richard A. Wendland

June, 1992

Thesis Advisor:

Raymond P. Shreeve

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Upgrade and Extension of the  
Data Acquisition System for  
Propulsion and Gas Dynamic Laboratories

by

Richard A. Wendland  
Lieutenant Commander, United States Navy  
B.S.A.E., United States Naval Academy, 1980

Submitted in partial fulfillment  
of the requirements for the degree of

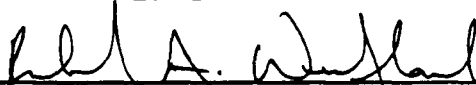
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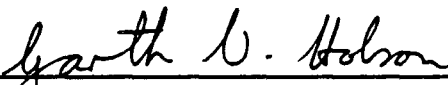


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# ABSTRACT

The goal of the present work was to upgrade the data acquisition system (DAS) in the high-speed building of the Turbopropulsion Laboratory (TPL) and to develop a high-speed acquisition capability for pressure measurements for both the TPL and the new Gas Dynamics Laboratory (GDL). Based on the use of the Hewlett Packard HP9000 Series 300 Computer as the system controller, a 96-channel high-speed pressure DAS was developed using Scanivalve ZOC-14 modules and a CALSYS2000 calibrator. The system allowed acquisition times for current wind-tunnel experiments to be revised from four minutes to eleven seconds. Also, new software was written to acquire data from existing rotary pneumatic Scanivalves and HP-IB compatible instrumentation so that all other existing acquisition capabilities were maintained in both laboratories.

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## I. INTRODUCTION

The Turbopropulsion Laboratory (TPL) consists of two large buildings, each with a central data acquisition system (DAS) serving multiple rotating and cascade test rigs. One building is for low-speed and one is for high-speed flow experiments. The Gas Dynamics Laboratory (GDL) consists of a single large building, closely adjacent to the other two, for which components for a central data acquisition system had been purchased, but not installed, at the inception of the present work. The GDL houses three blow-down wind tunnel facilities and a shock tube.

In planning the DAS for the GDL, commonality of the controller with the systems in the TPL was desirable in order to eliminate the need for students to learn different machines, to simplify the support task, and to interchange parts in the event of a failure. Since the TPL low-speed building was recently upgraded to use a Hewlett-Packard HP9000 Series 300 computer, two additional similar computers were purchased, one for the DAS new DAS and one to upgrade the DAS in the TPL high-speed laboratory. Thus the task in the present work was two-fold. First, software was required to be generated on the HP9000 which would enable all established DAS functions and experiments in the high-speed laboratory at the TPL to be maintained. Second, a high-speed scanning data

system was required to acquire pressure measurements in the short (minutes) duration blow-down wind tunnel tests in the GDL. Future upgrading in all laboratories would clearly depend on the experience gained in developing the high speed scanning system.

The pre-existing DAS's at the TPL incorporated Hewlett Packard HP-IB compatible scanners, digital voltmeters, system voltmeters, frequency counters and a locally developed HG-78K controller for pneumatic Scanivalves. Prior to the HP9000 acquisition, in earlier updates, the HP9830, HP9845 and HP1000 computers had been used as system controllers. Because of almost unlimited run-times of the rigs at the TPL, and the need largely to record many channels of "steady-state" measurements, the data-recording times were not a critical issue. [For "real-time" pressure measurements, a 16-channel 100 Khz capability was provided using a (non HP-IB) DMA input to the HP1000 from a now-obsolete HP5610A A/D converter].

Data acquisition was accomplished in the "steady-state" system, by computers executing individual data measurement instructions under program control. The maximum data collection rate was determined by the speed that the computers could execute individual instructions within the program between consecutive data measurement steps. P r e s s u r e measurements were made using the Scanivalve rotary pneumatic pressure sensing unit operated by the NPS HG-78K Controller. The Scanivalve unit sequentially stepped through its block of

ports collecting single pressure data once every 1.5 seconds. The HG-78K stepped the Scanivalve to the specified measurement port on commands executed by the computer. In summary, the pressure data acquisition rate was limited by the speed of the peripheral devices and by the computer's speed in executing program instructions.

The first task in the present work, to regenerate the software for the TPL "steady-state" DAS in HP BASIC 5.13 on the HP9000, served to become familiar with the computer and its programming, but no detailed report is included herein. The main task was to develop a high-speed scanning system for GDL, and this is documented in detail.

The hardware for the new system included the HP9000 Desk Top Computer System, HP6944A Multiprogrammer, Scanivalve ZOC-14 Electronic Scanning Pressure Module and CALSYS2000 Calibrator. The HP9000 serves as the computer-controller using the BASIC programming language. Data and program storage for the HP9000 is handled by a HP9153C Disc Drive incorporating a 40 mega-byte hard drive and 1.44 mega-byte 3.25" floppy drive. (The HP9153C replaced the older HP7906 Disc Drive and HP7970E Tape Drive of the HP1000 system).

The HP6944A combines several data acquisition devices (I/O Cards) into one unit. The significant feature of the HP6944A is its ability to perform specific data acquisition functions, and to control the data measurement steps without intervention from the host computer (HP9000). The HP6944A removes the



individual data measurement instructions of the program from the acquisition process, resulting in data rates which are limited only by the speed of the individual I/O card and the non-Hewlett Packard device.

In comparison with the TPL "steady-state" system, the ZOC-14 module replaces the low speed rotary Scanivalve and instead provides high speed electronic scanning of the pressure ports. The CALSYS2000 provides ZOC control and supplies calibration pressures to it, making the ZOC and CALSYS2000 a "packaged" pressure measurement system.

The software which was generated to integrate the HP9000, HP6944A and Scanivalve ZOC-14/CALSYS2000 system was designated as program SCAN\_ZOC\_05. The complete package of hardware and software is referred to hereafter as the ZOC-14 Data Acquisition System, or ZOC-14 DAS.

In the present document, Chapter Two describes and discusses the development of the ZOC-14 DAS. The hardware, individual component operation, integration of the components into a complete system, and the application programs to operate the DAS are discussed in detail. It is hoped that this chapter will serve as a manual for the system, and as a guide to those responsible for future extensions.

Chapter Three discusses the upgraded capabilities of TPL and GDL DAS's, potential extensions and outstanding issues. (The ZOC-14 DAS is fully operational, but requires resolution of these issues to optimize the system's performance).

Finally, conclusions are drawn and a particular recommendation is made in chapter Four.

Additional details are given in the Appendices. Appendix A contains the ZOC-14 DAS application program flow chart, the application program SCAN\_ZOC\_05, and associated utility programs. The utility programs are used to read and display the results of the data compiled by the SCAN\_ZOC\_05 program.

Appendix B contains four earlier versions in arriving at the SCAN\_ZOC\_05 program. The program evolved in steps, as knowledge was gained on the hardware operation and integration, and software programming. Each program is annotated with pertinent information to describe the program's functional routines, and are reported as an aid to future programming.

Appendix C contains a brief guide to managing data files provided by the ZOC-14 DAS collection process. A program is listed, and instructions provided, to view and delete selected data files from the hard drive. A sample print-out of the hard drive contents is provided, showing the data file listing and unique structure for the ZOC-14 DAS data files.

Appendix D provides a listing of all major programs developed for use on the HP9000 for the TPL. A compilation of all programs, listed in groups of "directories" contained on the HP9153C hard drive, is provided. The major program listings are divided into the categories of Turbocharger Performance, AE4431 Turbomachinery Design, and several sample

routines to operate devices, perform calculations, and  
manipulate files.

## II. ZOC-14 DATA ACQUISITION SYSTEM

### A. General Overview

#### 1. Hardware

The ZOC-14 Data Acquisition System (DAS) hardware includes the Scanivalve ZOC-14 Electronic Pressure Scanning Module (Figure 1), the Scanivalve CALSYS2000 Calibration System (Figure 2), the Hewlett Packard HP6944A Multiprogrammer (Figure 3), and the Hewlett Packard HP9000 Desk Top Computer System and peripherals (Figure 4).

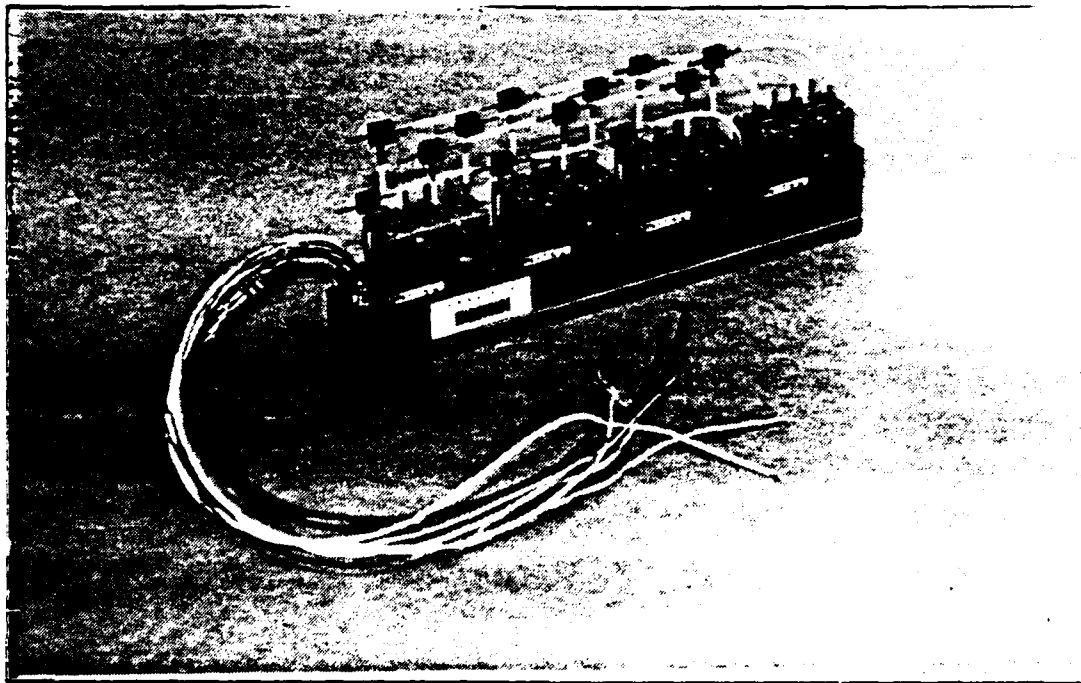


Figure 1 ZOC-14 Electronic Pressure Scanning Module

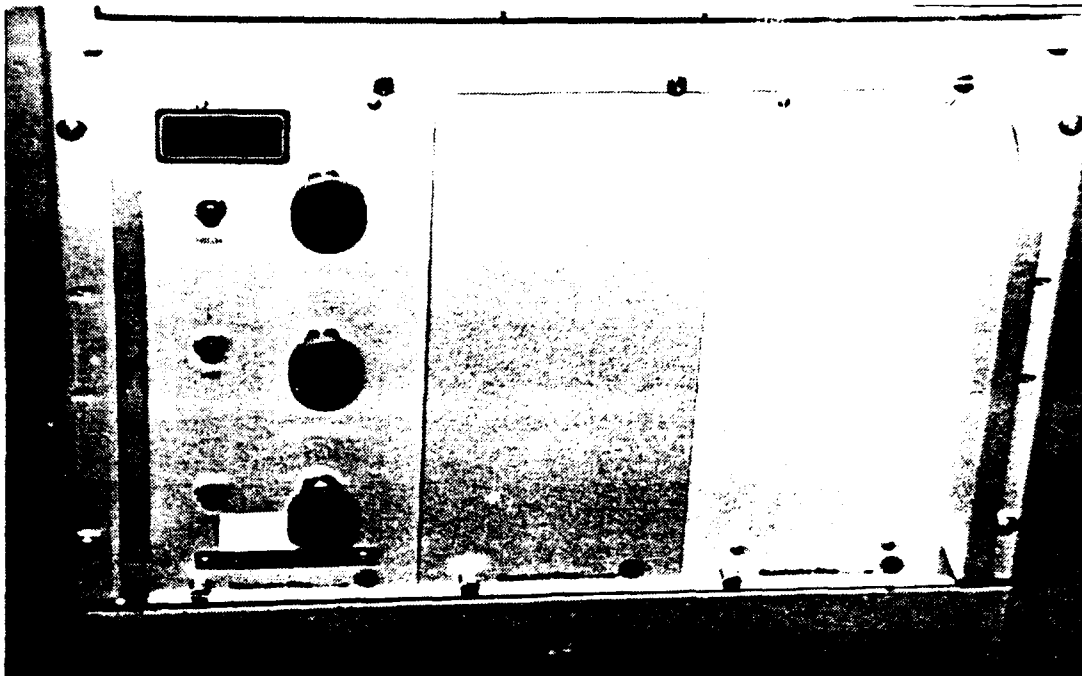


Figure 2 CALSYS2000 Calibration System

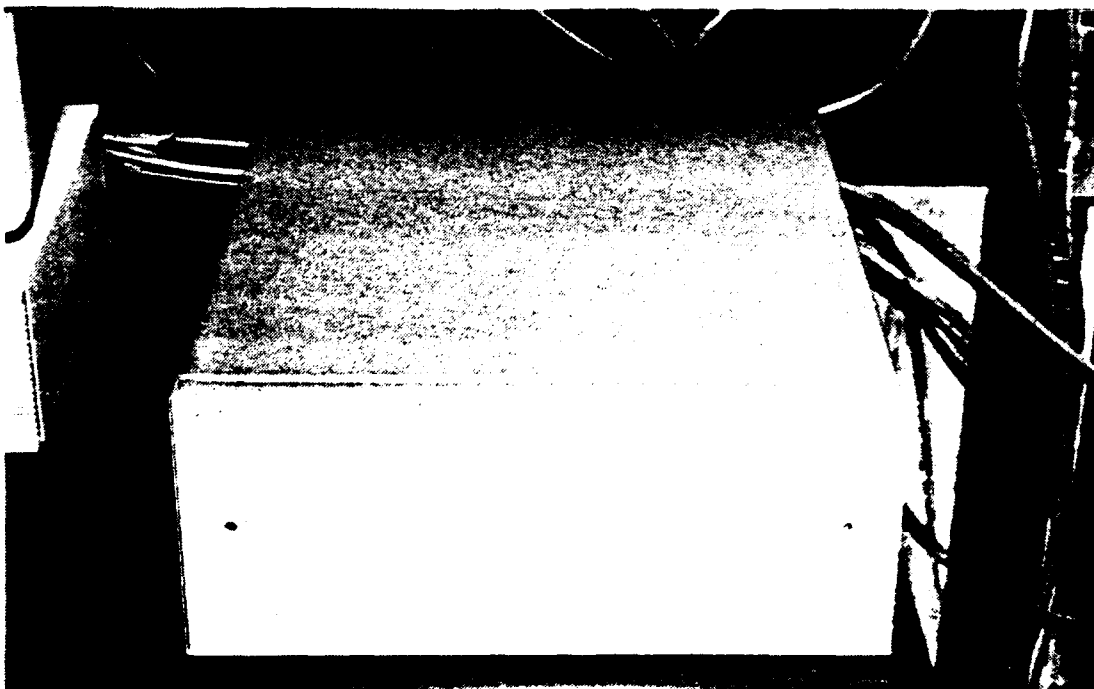
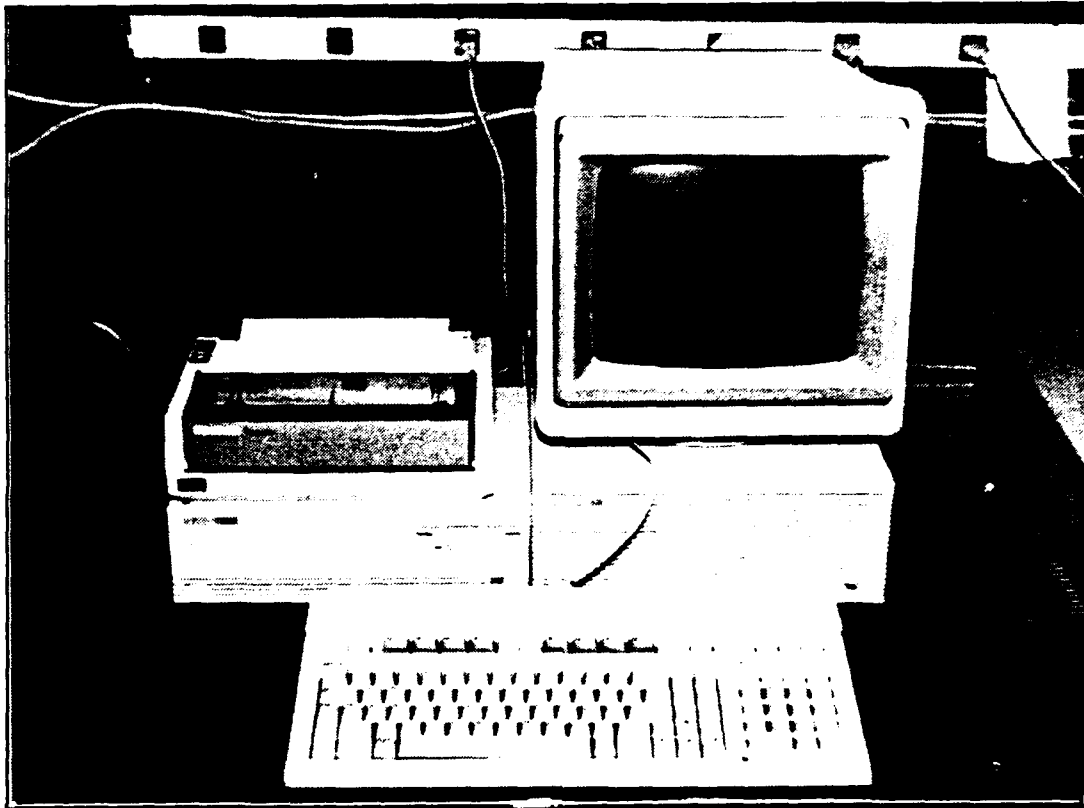


Figure 3 HP6944A Multiprogrammer



**Figure 4 HP9000 Computer System**

## **2. Software and Literature**

The HP9000 is provided with BASIC 5.13 software. On-line compilation occurs when a program is executed by the RUN command. This user-friendly feature allows expeditious changes to be made in a program without the separate time consuming re-compilation process required by other high level programming languages. The result is the ability to RUN a program, change the program, and RUN the program again with minimal effort and time, making BASIC an ideal tool for an engineer.

The BASIC software system and documentation includes the necessary firmware provided on seven 3.25" floppy disks and twelve manuals describing the loading, utilization, and maintenance of BASIC (Figure 5)[Ref. 1 through Ref. 12].

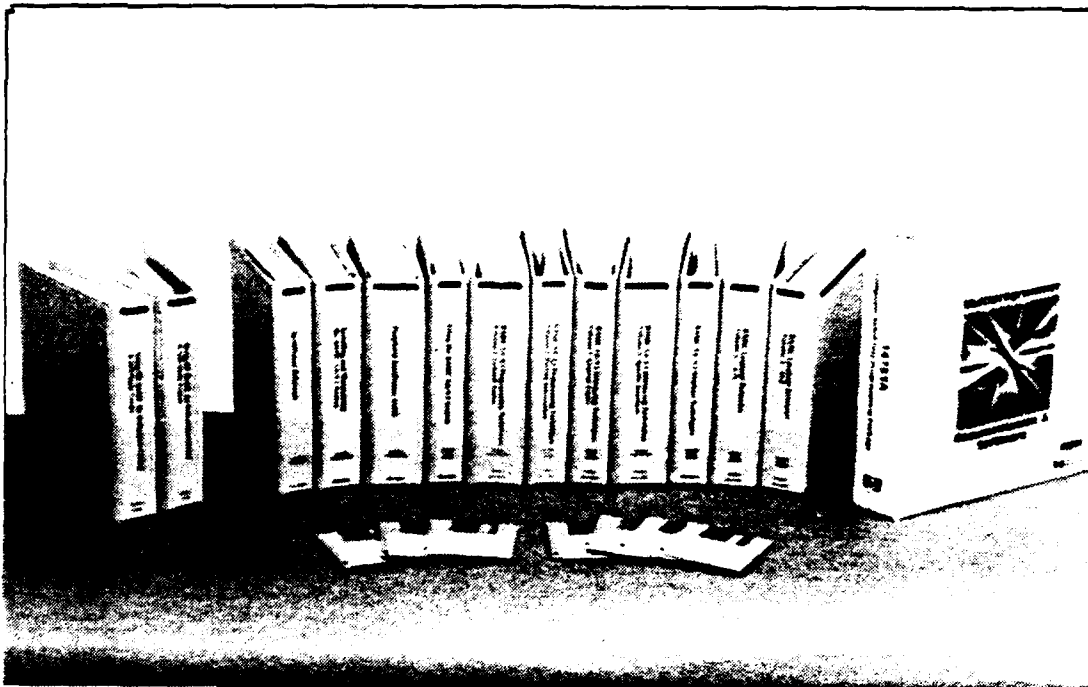


Figure 5 Hewlett Packard BASIC Program and Literature

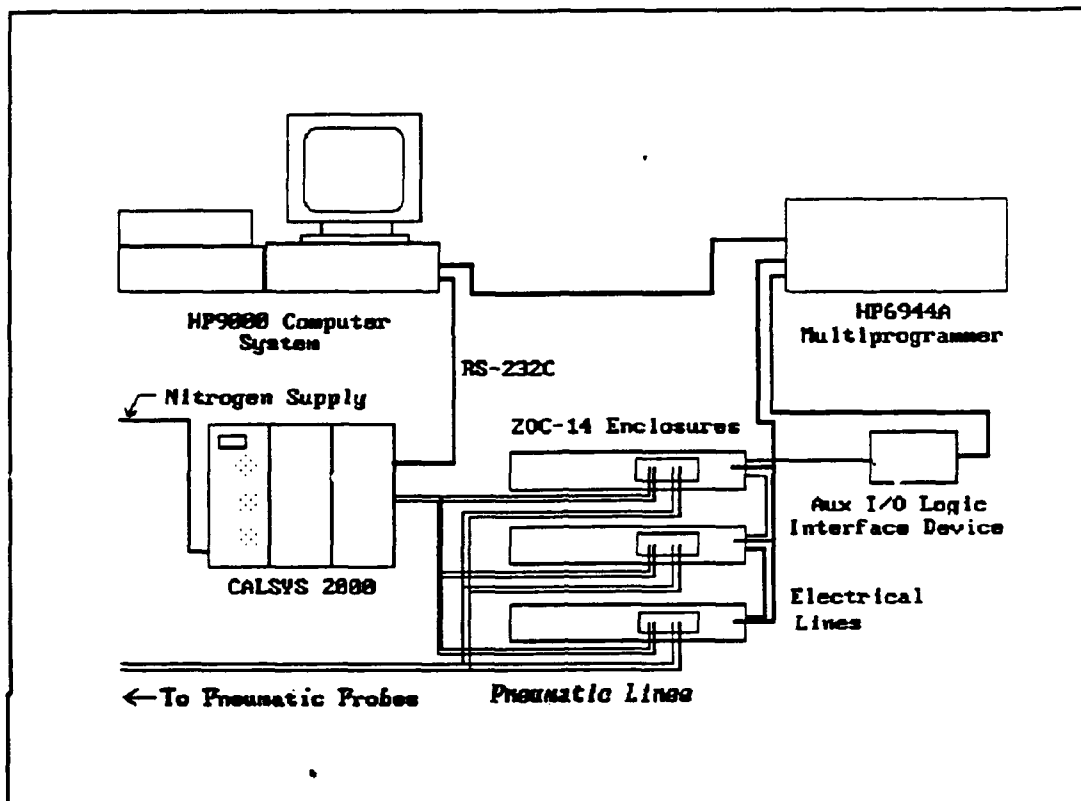
The two volume Hewlett Packard Educational Package (Figure 5)[Ref. 13 through Ref. 14] is vital to quickly learn BASIC and its implementation with the HP9000 and the line of Hewlett Packard peripheral devices. This package condenses all the pertinent information contained in the BASIC program manuals. The novice programmer will find that the Educational Package provides the necessary fundamentals in how to use BASIC. The advanced programmer will be regularly referencing the BASIC program manuals for his programming requirements.

The HP14753A CAT Program Package (Figure 5) [Ref. 15] comprises the firmware and documentation required to set-up and operate the HP6944A Multiprogrammer. Details of this package will be discussed later in this chapter.

### 3. TPL ZOC-14 DAS System

The TPL ZOC-14 DAS System is an integration of all the aforementioned hardware, firmware, and newly developed software into an application package. The capability of the system is the ability to collect pressure data on multiple channels at high sampling rates, reduce the raw data, and store the reduced data using a user friendly, menu-driven operating program on the HP9000 computer. A schematic of the ZOC-14 DAS System is illustrated in Figure 6. The HP9000 computer is the central controlling device for the system. Software on the HP9000 controls data collection from the CALSYS2000 and HP6944A, data reduction, and data storage to the computer's hard drive and floppy drive. The HP6944A interfaces with the ZOC-14 modules providing electronic port selection, receiving analog voltages and converting to digital data. The CALSYS2000 is controlled by the HP9000, provides calibration pressure to the ZOCs, pneumatically sets the ZOC's operating modes, and provides digital data conversion of calibration pressure to the HP9000. The ZOC-14 module converts pneumatic pressures to analog voltage signals which are collected in the HP6944A.





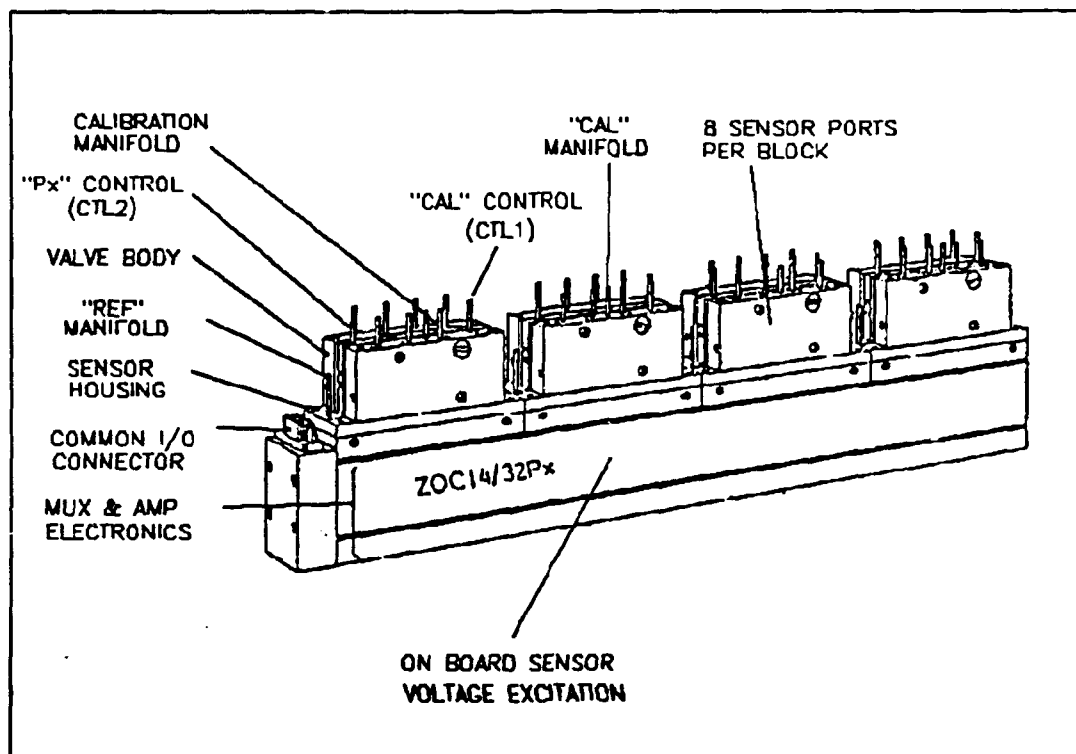
**Figure 6 ZOC-14 Data Acquisition System**

## **B. Hardware Description**

### **1. ZOC-14 Electronic Pressure Scanning Module**

#### **a. Principle of Operation**

The ZOC-14 is a 32 port electronically switched pressure sensing device. Internally, pressures are converted through semi-conductor strain gages to an analog voltage output signal for each selected port (Figure 7). The electronic switching feature allows the individual strain gages to be selected at random, and the output voltage signal to be read.



**Figure 7 ZOC-14 Module Diagram**

Each ZOC contains a series of valves that are pneumatically switched to set an operating mode. Shown in Figure 8 are the ports P1 through Px which are connected by pneumatic pressure tubing to the apparatus or probe where pressure is to be measured, such as the model in a wind tunnel. The Calibration Manifold and Sensor Reference Pressure Manifold are connected to the CALSYS2000 to receive a reference calibration pressure to be measured by the ZOC for calibration purposes. CAL Control (CTL1) and Px Control (CTL2) are pneumatic control lines that position the valves to set the required operating mode in the ZOC. CAL and Px control pressures are provided by the CALSYS2000.

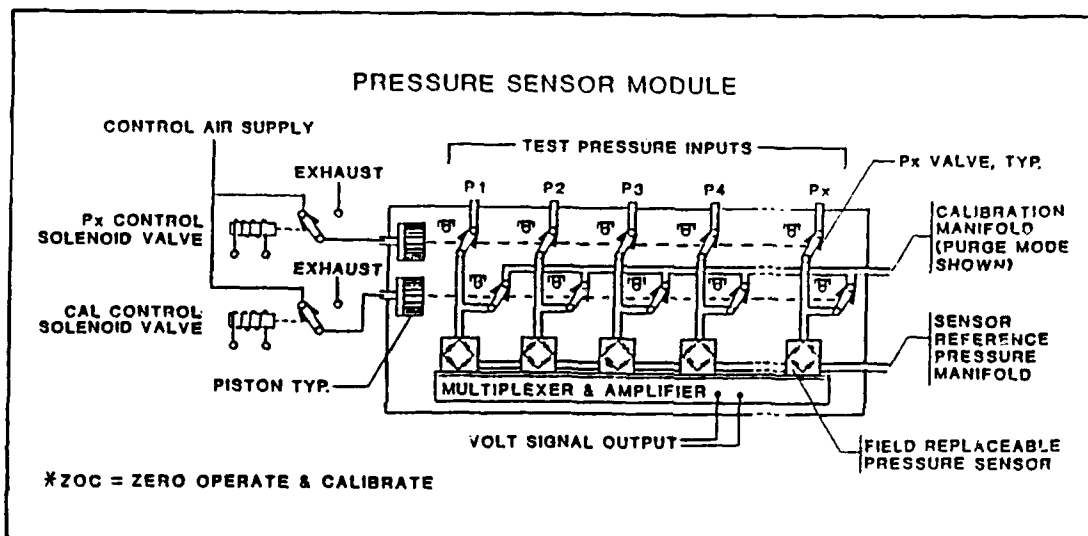


Figure 8 ZOC-14 Valve Body Schematic

The ZOC operates on the principle "ZERO OPERATE AND CALIBRATE"; hence the name "ZOC". This principle involves a two phase sequence. The first phase sets the ZOC into an "OPERATE" mode and experimental pressure data at pressure ports P1 through Px are converted and recorded. The second phase sets the ZOC into the "CALIBRATE" mode. The CALSYS2000 provides a calibration pressure through the Calibration Manifold and Sensor Reference Pressure Manifold to each strain gage. Calibration pressure data are then collected from the ZOC for each port by the HP6944A. The HP9000 collects the pressure data from the HP6944A and digital converted calibration pressure data from the CALSYS2000. These two sets of data are plotted against each other to get a calibration curve for each ZOC strain gage.

Figure 9 illustrates the ZOC's four modes of operation. In the OPERATE mode, P1 pressure is routed to the

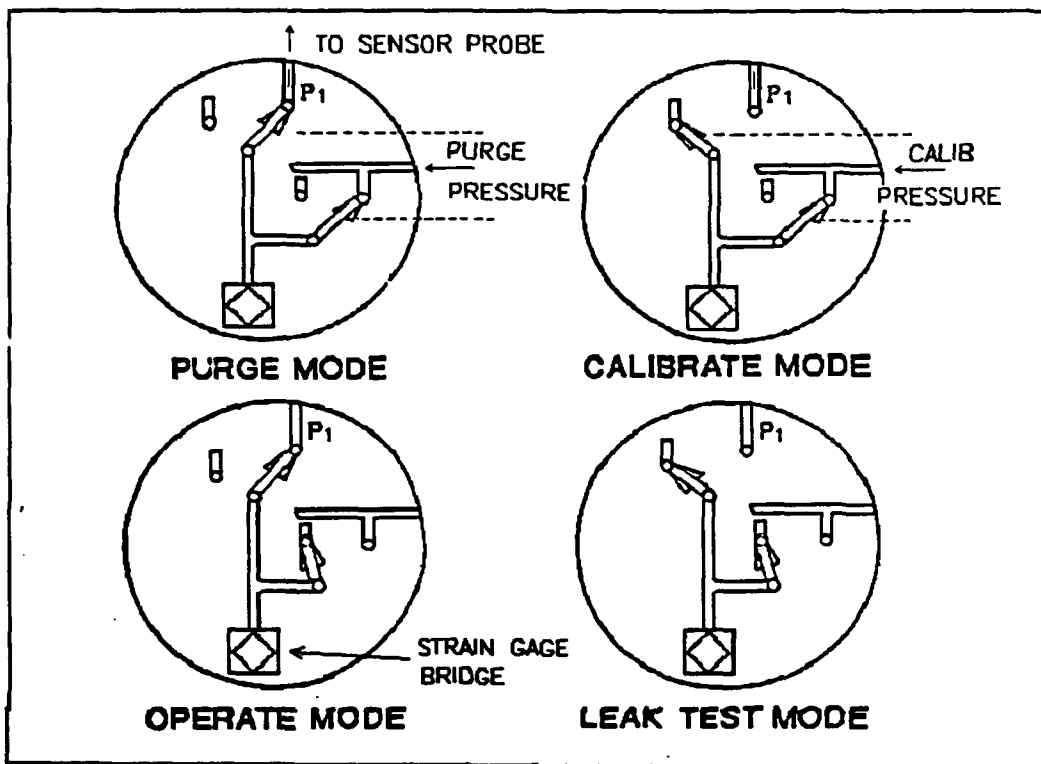


Figure 9 ZOC-14 Pneumatic Switching Modes

strain gage, and the Calibration Manifold is isolated. In the CALIBRATE mode, calibration pressure is routed to the strain gage, and the P1 pressure is isolated. The PURGE and LEAK TEST modes are used for clearing pressure lines and for diagnostic checks, respectively.

The Multiplexer and Amplifier section (Figure 8) facilitates the ZOC's high speed scanning capability. The multiplexer is driven by a five bit address input signal (A0 through A4) from the HP6944A, selecting a specified port from 1 to 32 in binary code. The ZOC's electronic module is illustrated schematically in Figure 10. The analog output signal processing is accomplished within the electronic

Figure 10 ZOC-14 Electronics Schematic

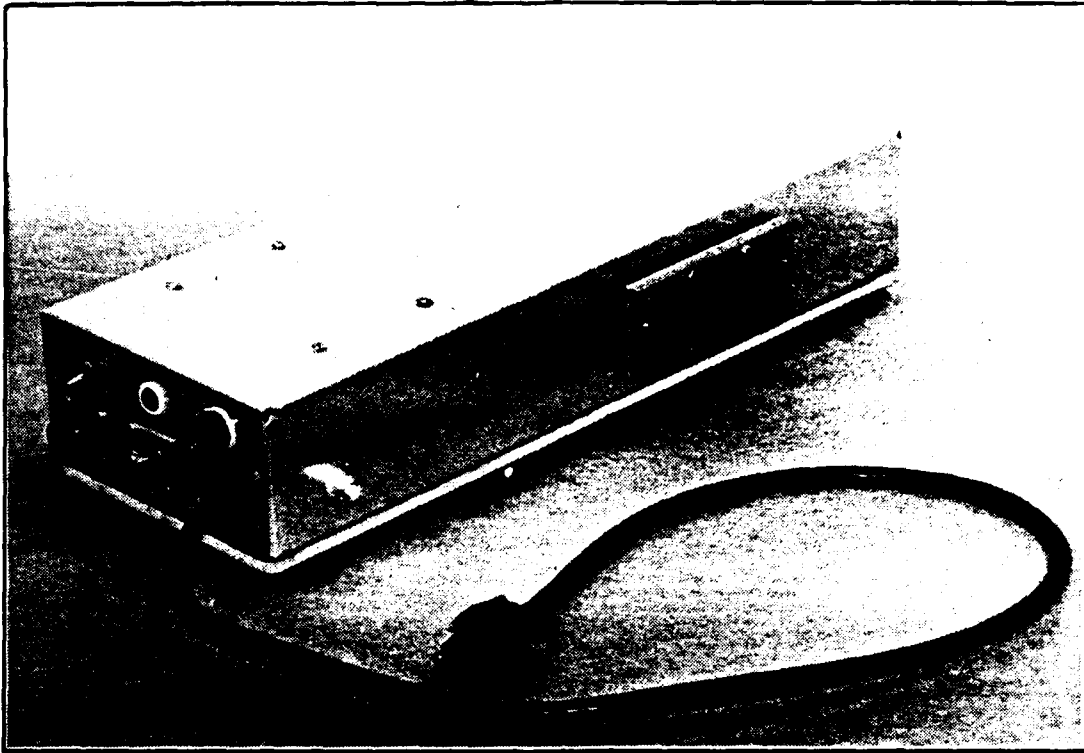
section of the ZOC.

Reference 16 provides all pertinent specifications, descriptions of the design and operation, and is the source document for the above technical information on the ZOC-14 Module.

**b. ZOC-14 Enclosure**

The ZOC-14 Enclosure was designed and built at NPS to provide a mobile and versatile module which was convenient for electronic and pneumatic connections, and provided protection in the laboratory environment. Components in the enclosure include one ZOC-14 Module (Figure 1), a 115 VAC power supply, a BNC connection for the output signal, Cannon plugs for the ZOC address input, and a pneumatic connection plate for measurement, control, and calibration pressure lines (Figure 11).

Each Px port on the ZOC-14 module has a corresponding port connection on the pneumatic connection plate. The connection plate port numbers 1 through 32 correspond to the ZOC's ports as selected by the binary address code. The Px Control, CAL Control, CAL, and REF ports on each valve block (Figure 7) are each connected to a common line as illustrated in Figure 12. The Px Control line is routed to port number 33, CAL Control to port number 34, CAL to port number 35, and REF to port number 36. Ports 37 through 48 are not used.



**Figure 11 ZOC-14 Enclosure**

The enclosure's electrical wiring is illustrated schematically in Figure 13. The two-five pin Cannon plugs are wired in parallel to jumper ZOC address line connection points between adjacent enclosures. This feature allows for one address line from the HP6944A to be connected to the first enclosure Cannon plug. The second enclosure receives its ZOC address signal from the second Cannon plug on the first enclosure by a jumper line. The third and following enclosures receive their ZOC address signals in the same sequence of connections.

A significant capability of the ZOC address control feature, in connection with the HP6944A, is the

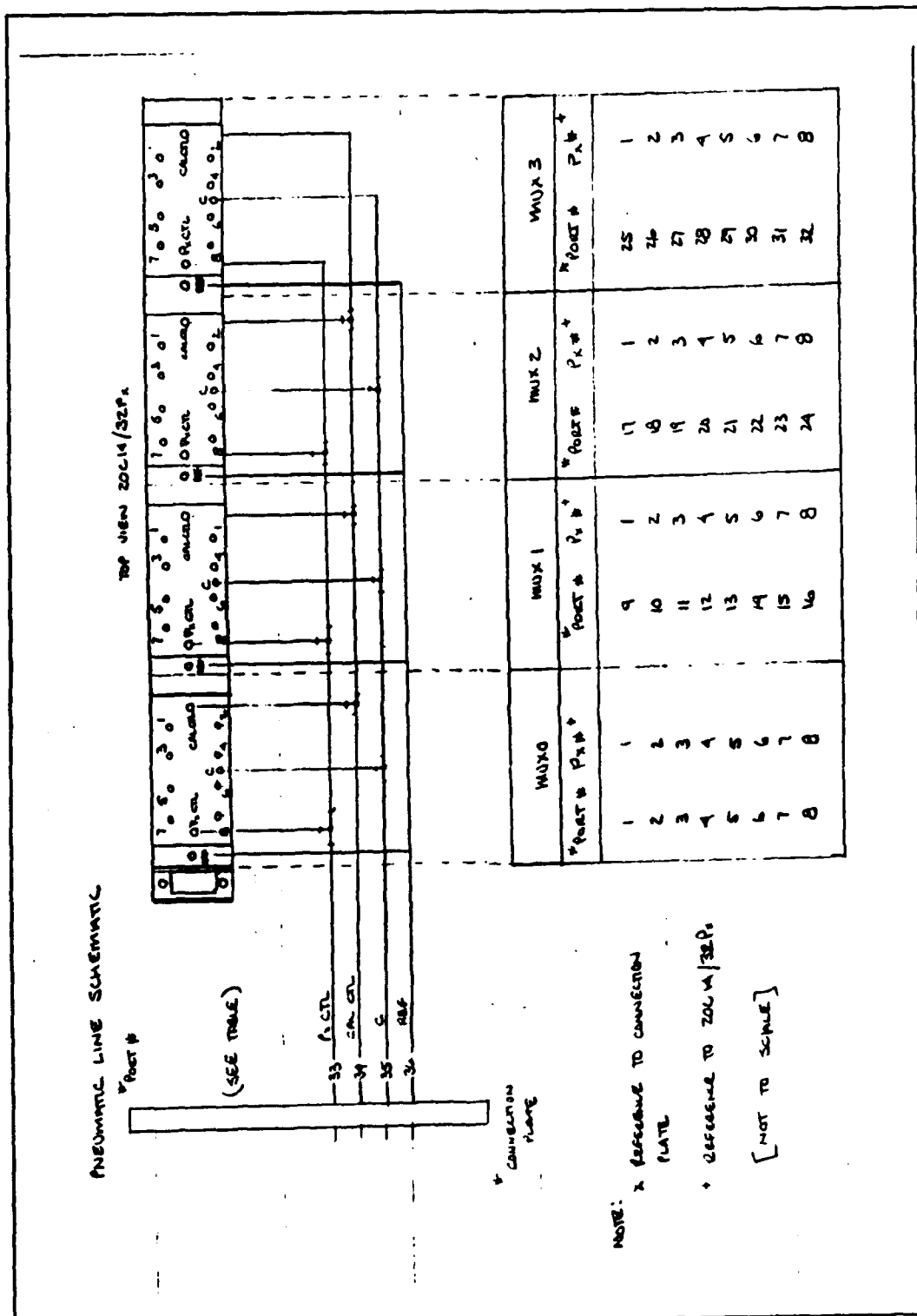


Figure 12 ZOC-14 Enclosure Pneumatic Line Schematic



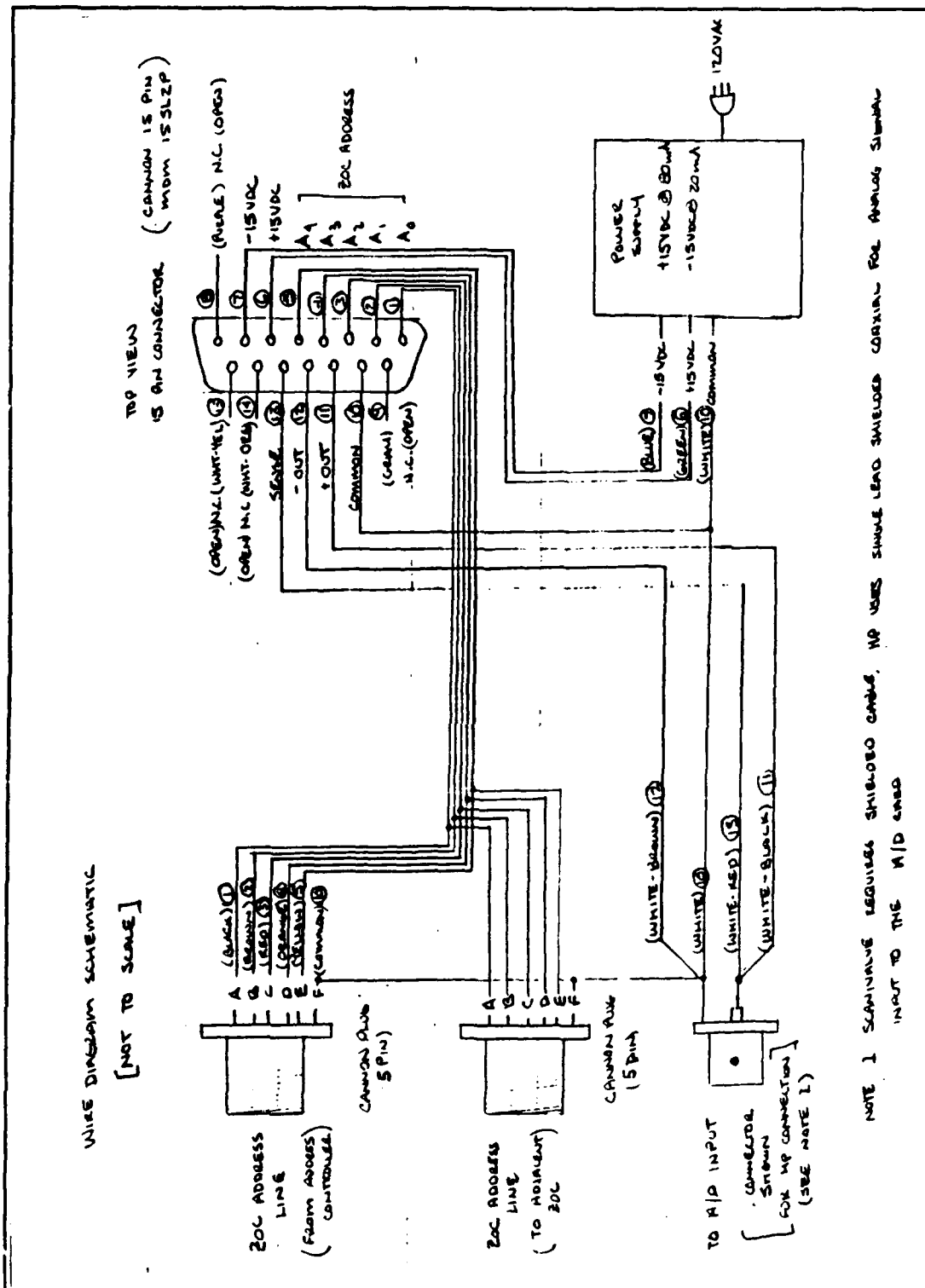


Figure 13 ZOC-14 Enclosure Electronics Schematic

ability to simultaneously collect pressure data from corresponding ports on a multiple ZOC configuration. This capability could play a significant role in determining the pressure behavior at two or more different points at the same instance in time. The number of instantaneous data points is determined by the number of ZOCs connected into the ZOC-14 DAS System.

## 2. CALSYS2000 Calibration Module

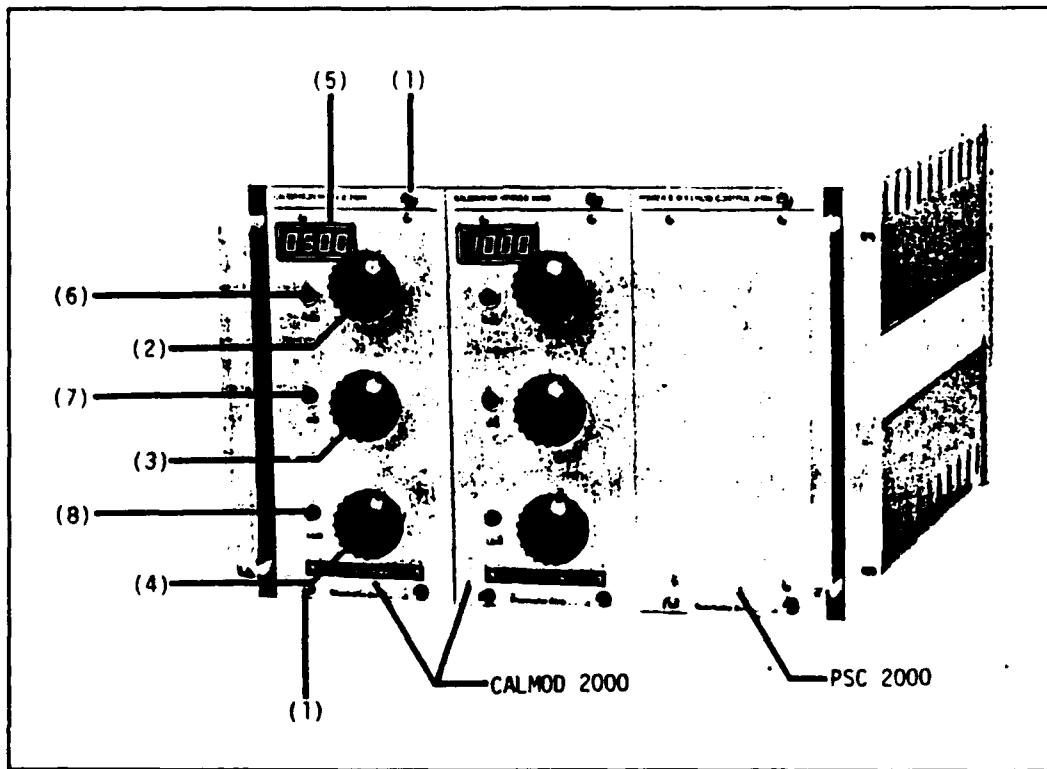
### a. Description

The CALSYS2000 interfaces the ZOC module with the HP9000 computer by setting the ZOC mode selection as commanded by the HP9000, providing calibration information to the HP9000, and sending a reference calibration pressure to the ZOC for calibration purposes. Figure 14<sup>1</sup> shows a front view of the CALSYS2000 module.

The CALSYS2000 is comprised of a Calibration Module (CALMOD 2000) and a Power and Solenoid Control (PSC 2000) module. Figure 15 illustrates the external pneumatic and electrical line connections between the two modules, the nitrogen supply source and ZOC pneumatic line connections as seen in a rear view of the CALSYS2000 as it is installed at the TPL.

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<sup>1</sup> Figure 14 is found in Ref. 17, page 10, as Figure 1.



**Figure 14 CALSYS2000 Calibration System**

**b. Calibrator Module (CALMOD 2000)**

The CALMOD 2000 provides the electronic interface with the HP9000 through the serial RS-232C data link with a built-in processor. The processor responds to various commands from the HP9000 and issues control signals to actuate an array of solenoids within the CALMOD and PSC. The selective setting of the solenoids routes reduced nitrogen gas pressure to set the ZOC modes, and provide a regulated calibration reference pressure for ZOC transducer calibration. An internal Pressure Standard module samples the calibration pressure and provides a proportional analog voltage value to the processor. The processor's internal A/D and mathematical

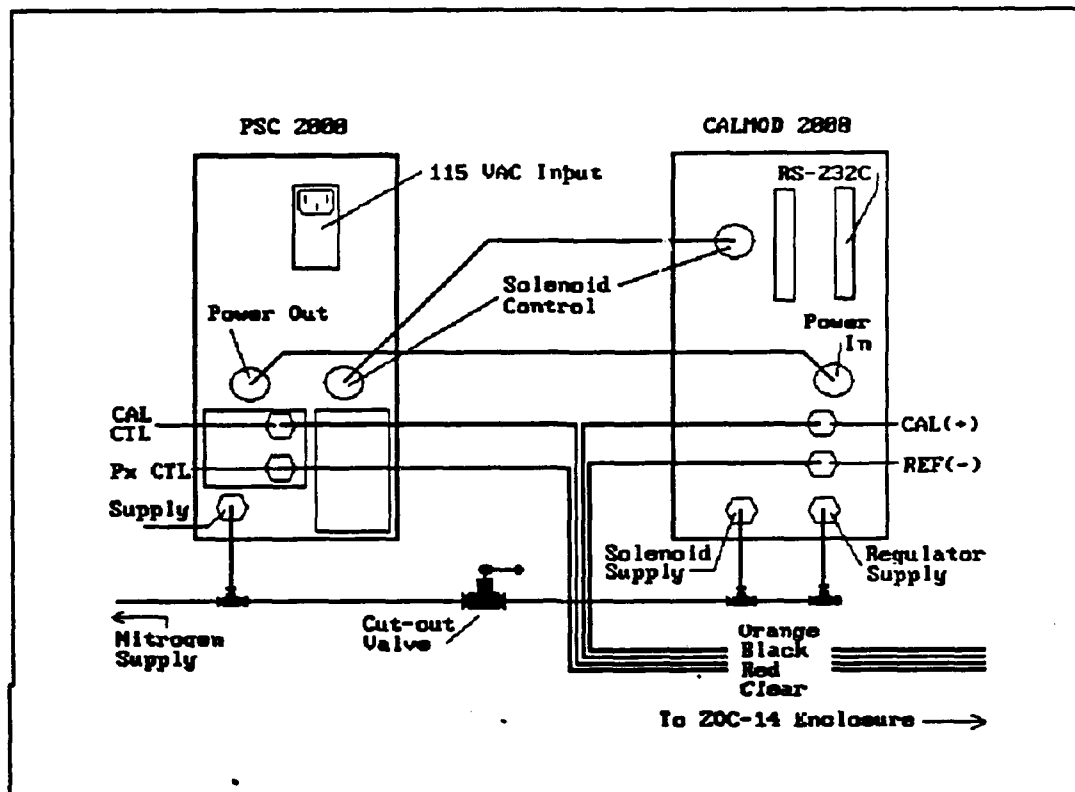


Figure 15 CALSYS2000 External Line Connections

processors return a digital measure of the pressure in either psia or inches of mercury. The CALMOD is currently set for inches of mercury. The processor provides this digital pressure value at the front window on the CALMOD (item 5, Figure 14), and also returns the value to the HP9000 following a "read pressure" command.

The CALMOD has three manually adjustable pressure regulators (items 6,7,8 in Figure 14) and associated pressure display buttons (items 2,3,4 in Figure 14). These regulators provide three different reference calibration pressures that the ZOC uses for calibration. During the calibration mode, each one of the three calibration pressures are sequentially

sent to the ZOC and the Pressure Standard. To calibrate the ZOC for positive pressures, the calibration pressure is provided through the Calibration Manifold to the strain gage transducers. To calibrate the ZOC for negative pressures, the calibration pressure is provided through the Sensor Reference Pressure Manifold to the backside of the strain gage transducer. Pressure data from the CALSYS2000 and ZOC are collected by the HP9000 and reduced to obtain calibration curves for each ZOC transducer.

Figure 16<sup>2</sup> shows the rear panel of the CALMOD 2000 with all the installed connection ports. Figure 15 illustrates the ports currently used at TPL. The CALMOD receives a common low-pressure supply of nitrogen gas to the Solenoid Supply and Regulator Supply connections. Regulated calibration pressure is supplied to the ZOC Calibration Manifold through the CAL(+) connection, and the Sensor Reference Pressure Manifold through the REF(-) connection.

Figure 17<sup>3</sup> shows the pneumatic lines between the CALSYS2000 and ZOC units. The TPL currently has two 15 psid and one 50 psid ZOCs. These ranges require a nominal 90 psi Regulated (Instrument) Air Supply to properly operate<sup>4</sup>. The solenoid supply is 90 psi for both the CALMOD and PSC.

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<sup>2</sup> Figure 16 is found in Ref. 17, page 12, as Figure 2.

<sup>3</sup> Figure 17 is found in Ref. 17, page 21, as Figure 5.

<sup>4</sup> Refer to Ref. 17, dwg 16202, sht 1 of 9, in back of ref. 17.

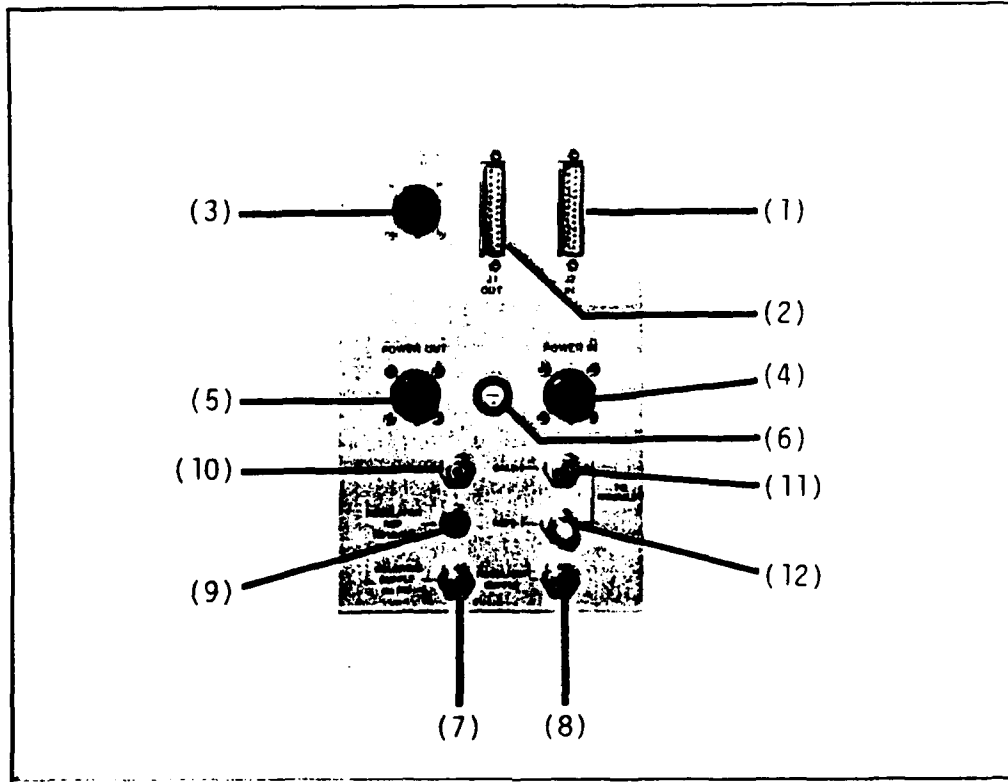


Figure 16 CALMOD 2000 Rear Panel

c. Power and Solenoid Control Module (PSC 2000)

The PSC provides the CALSYS2000 electrical power and pneumatically controls the ZOCs. Figure 18 shows the rear panel of the PSC with all external connections. Electrical power is supplied to the CALMOD through an electrical jumper between the Power Out (item 3 in Figure 18) and Power In terminals shown in Figure 15. The PSC contains the solenoids which route control air, CAL CTL and Px CTL (item 5 in Figure 18) to the ZOC for mode selection. These two solenoids are controlled by the CALMOD through an electrical cable connecting the Solenoid Control connections (item 3 in

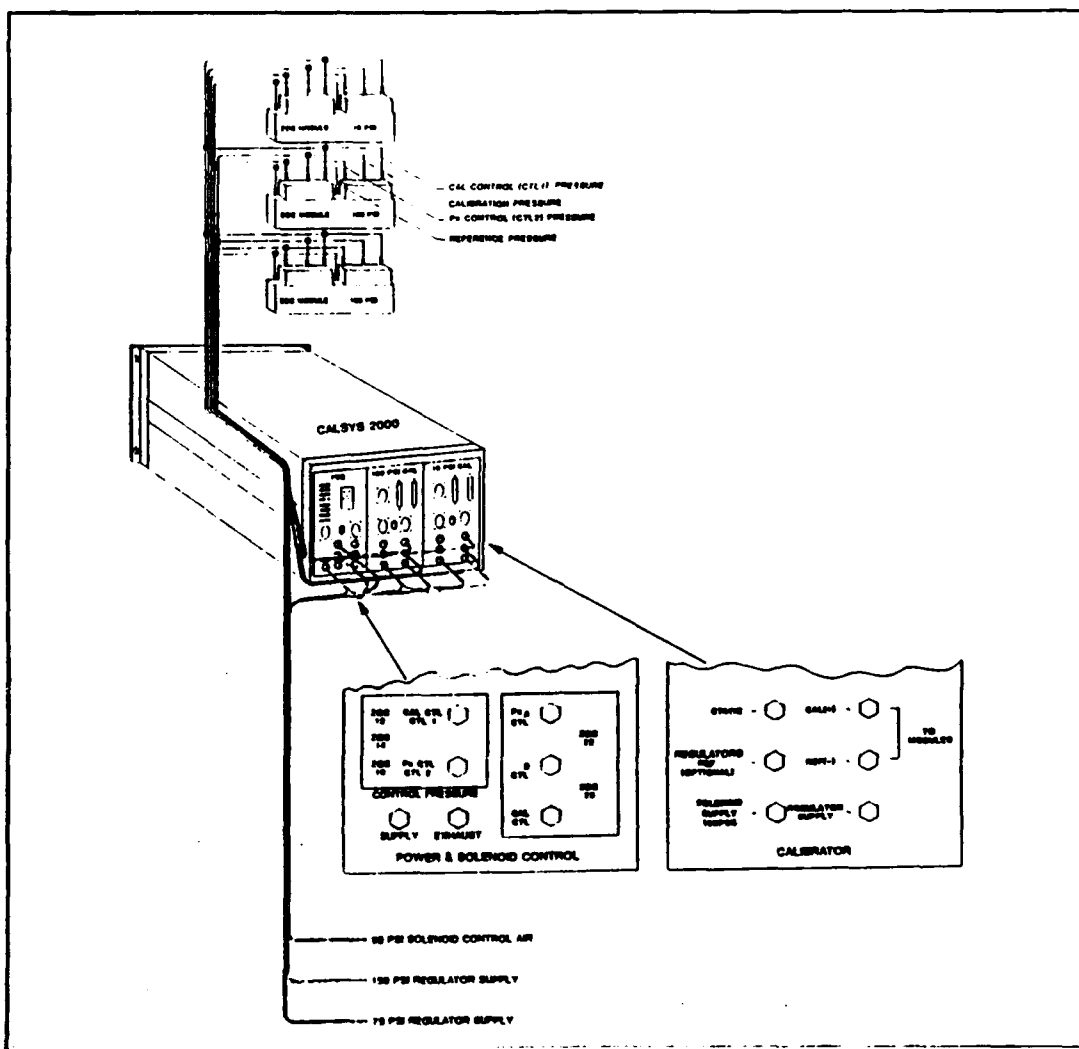


Figure 17 CALSYS2000-ZOC Pneumatic Hook-up

Figure 16 and item 4 in Figure 18). ZOC control gas to the solenoids is supplied at 90 psia from a high pressure nitrogen cylinder through the Supply port (item 7 in Figure 18).

#### d. CALSYS2000 Operation

The CALSYS2000 communicates with the HP9000 Computer through the RS-232C serial data link using ASCII character format commands. The commands used for the ZOC-14

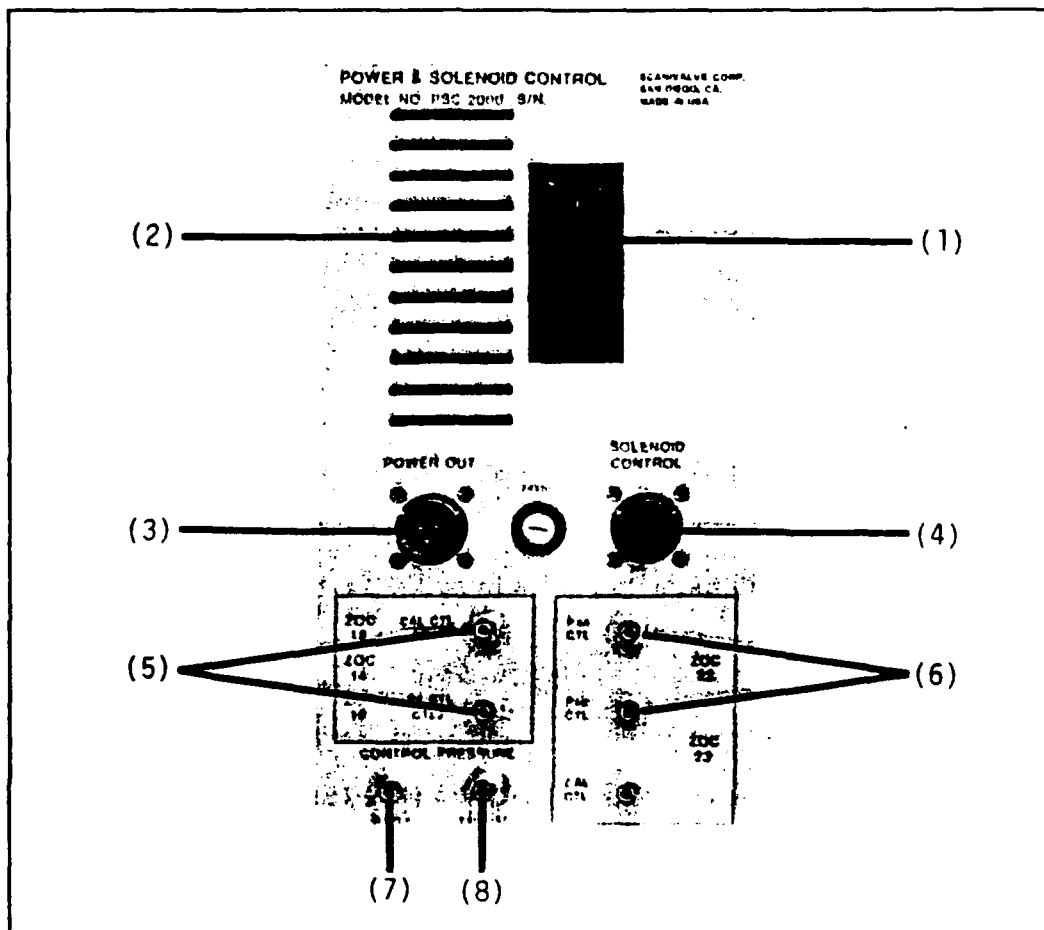


Figure 18 PSC 2000 Rear Panel

DAS are of two types:

- ◆ Commands from the HP9000 to set ZOC and CALSYS2000 modes by the actuation of control solenoids.
- ◆ Commands to provide pressure data to the HP9000, read from the Pressure Standard.

The command format for communications requires the HP9000 command statement to have the following ASCII character code format:

aCC(CR)



The "a" is the CALMOD address character which is currently "1" for the only CALMOD installed in the CALSYS2000 at the TPL. A second CALMOD would have the address character of "2". The "CC" part is the applicable command code such as "PH" which is discussed later. The "(CR)" is for a ASCII carriage return character which is "13" in decimal format.

The commands used to set ZOC and CALSYS2000 modes are summarized below:

**OPERATE mode** - This mode allows pressure to be measured by the ZOC by setting the valves in the ZOC to route Px air directly to the strain gage. Calibration functions are at idle. The OPERATE mode is the CALSYS2000 condition when it is first initialized or powered-up.

- ◆ aIC      Initialize Calibrator to set the CALSYS2000 to its power-up condition

**CALIBRATION mode** - This mode is set at the ZOC. Calibration reference pressure is sent to the ZOC, and all gas is routed to the Pressure Standard for display on the CALMOD window, and made available to the HP9000.

- ◆ aPH      Route high pressure gas from Regulator #1 to the ZOCs through the Calibration Manifold
- ◆ aPM      Route medium pressure gas from Regulator #2 air to the ZOCs through the Calibration Manifold
- ◆ aPL      Route low pressure gas from Regulator #3 to the ZOCs through the Calibration Manifold

- ◆ aZO      Gas in the Calibration and Reference Pressure Manifolds is equalized to atmospheric pressure in these manifolds
- ◆ aNL      Route low pressure gas from Regulator #3 to the ZOCs through the Reference Pressure Manifold
- ◆ aNM      Route medium pressure gas from Regulator #2 to the ZOCs through the Reference Pressure Manifold
- ◆ aNH      Route high pressure gas from Regulator #1 to the ZOCs through the Reference Pressure Manifold

**Read Pressure** - The CALMOD is asked for the current pressure value being sampled by the Pressure Standard. This command is used only by the ZOC-14 DAS program during the Calibration Mode. When the CALSYS2000 is in its "initialized condition", the Pressure Standard reads atmospheric pressure.

- ◆ aRP      Reads the pressure sampled by the Pressure Standard and returns the value in inches of mercury in ASCII character format:  
           "+/-1.23456E+78 at a"

Reference 17, Chapter 4, discusses the details and available command codes use by the CALSYS2000. The above codes are only used in the ZOC-14 DAS program with the HP9000. The CALSYS2000 is designed to operate from any PC using a standard modem control program.

The HP9000 and BASIC programming language required a modification of the CALSYS2000's command format factory settings. The Line-feed (LF) ASCII character in the command line corrupted the command message to the CALSYS2000 on any subsequent command following the initial HP9000 command.

Deletion of the LF from the HP9000 command resulted in uninterrupted command of the CALSYS2000.

[In its factory configuration, the CALMOD "handshakes" with a host computer using a "prompt record" to respond to a host computer command. (See Reference 17). Following a command issued to the CALMOD, the HP9000 would receive an interrupt error and halt the program. The BASIC line commands to handle the CALMOD prompt record could not be determined. Subsequently, the factory-set prompt record "(CR)(LF)(;)" was deleted to allow the HP9000 to continue without an interrupt error. Deletion of the prompt record "(CR)(LF)(;)" was accomplished by setting the "Null" prompt record. The Null prompt record was set into the CALMOD processor using the command " SMON " followed by " BP 1 ". The commands were communicated using a 386 PC with a modem-control program that performed computer to computer communication. The first command set the Null prompt record, the second command "burned" the Null prompt record into the CALMOD's PROM.]

#### e. CALSYS2000 Gas Supply System

The CALSYS2000 requires instrument quality air meeting ISA-S7.3 [Ref. 17, page 18]. The use of commercial bottled nitrogen gas more than satisfied this requirement. The supply system for the CALSYS2000 at TPL is illustrated in Figure 19. Nitrogen gas is reduced through a standard

regulator set at 90 psi, providing Solenoid Control and Regulator Air.

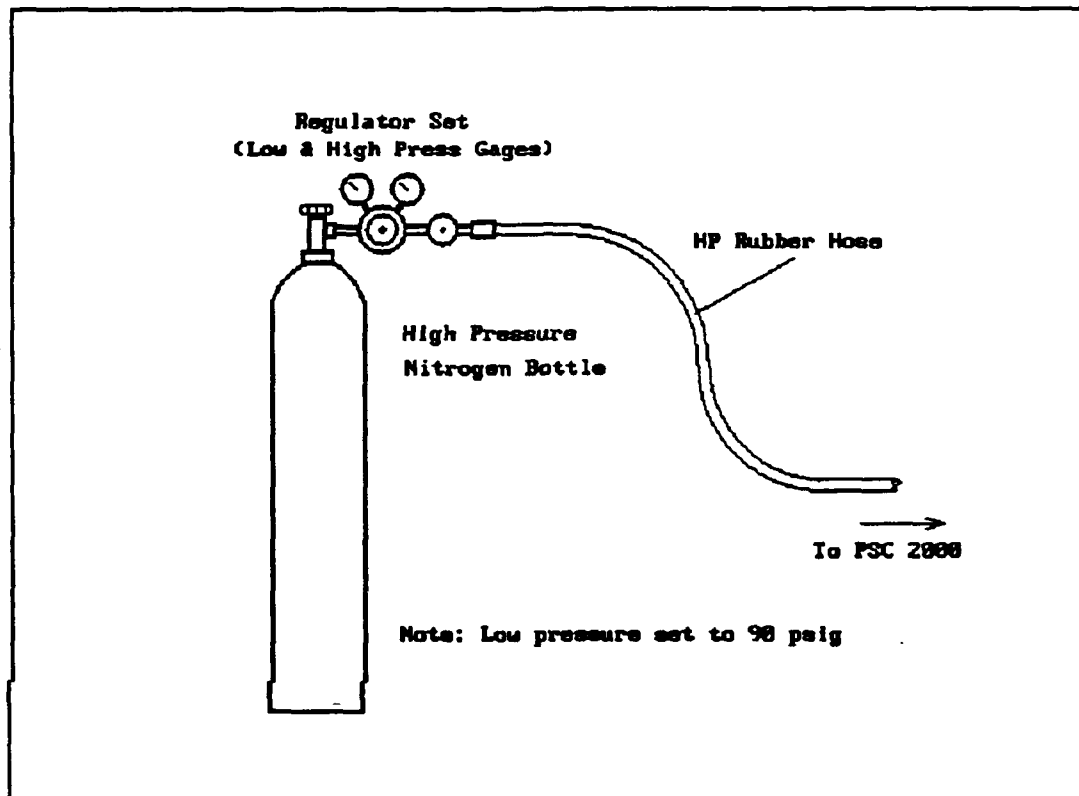


Figure 19 CALSYS2000 Nitrogen Supply

A cut-out valve (Figure 15) is installed between the PSC and CALMOD to minimize nitrogen gas consumption. The valve is set closed (handle down) when the CALSYS2000 is used in the OPERATE mode. The valve is opened for the CALIBRATE mode. Higher gas consumption occurs due to the design of the regulators in the CALMOD, which bleeds off gas to maintain a constant pressure setting.

### 3. Hewlett Packard Multiprogrammer (HP6944A)

#### a. General Description

The HP6944A (Figure 3) is a self-contained module with removable I/O cards which control various device operations or functions and interface with the HP9000. I/O cards are easily installed or removed by sliding the card into or out of an I/O slot in the enclosure. The HP9000 communicates with the I/O card through the HP6944A internal processor and Backplane Edge Connector which the installed I/O card plugs into. Electrical power supplies for the I/O cards are contained in the HP6944A enclosure. The HP6944A can support up to 16 I/O cards, depending on the cards' electrical power requirements. Figure 20 shows the HP6944A with the eight I/O cards and associated "edge plane" connecting cables used for the ZOC-14 DAS.

Reference 18 provides a detailed description of the HP6944A and a brief description of all the I/O cards available for the HP6944A. The I/O cards used in the ZOC-14 DAS are described in the following paragraphs.

#### b. I/O Cards

##### (1) 500 Khz A/D Card (HP69759A)

The A/D card provides analog to digital signal conversion from the ZOC-14 module. One A/D card is required for each ZOC. The card has a capability of performing A/D conversions at a rate of up to 500 Khz. The card is factory

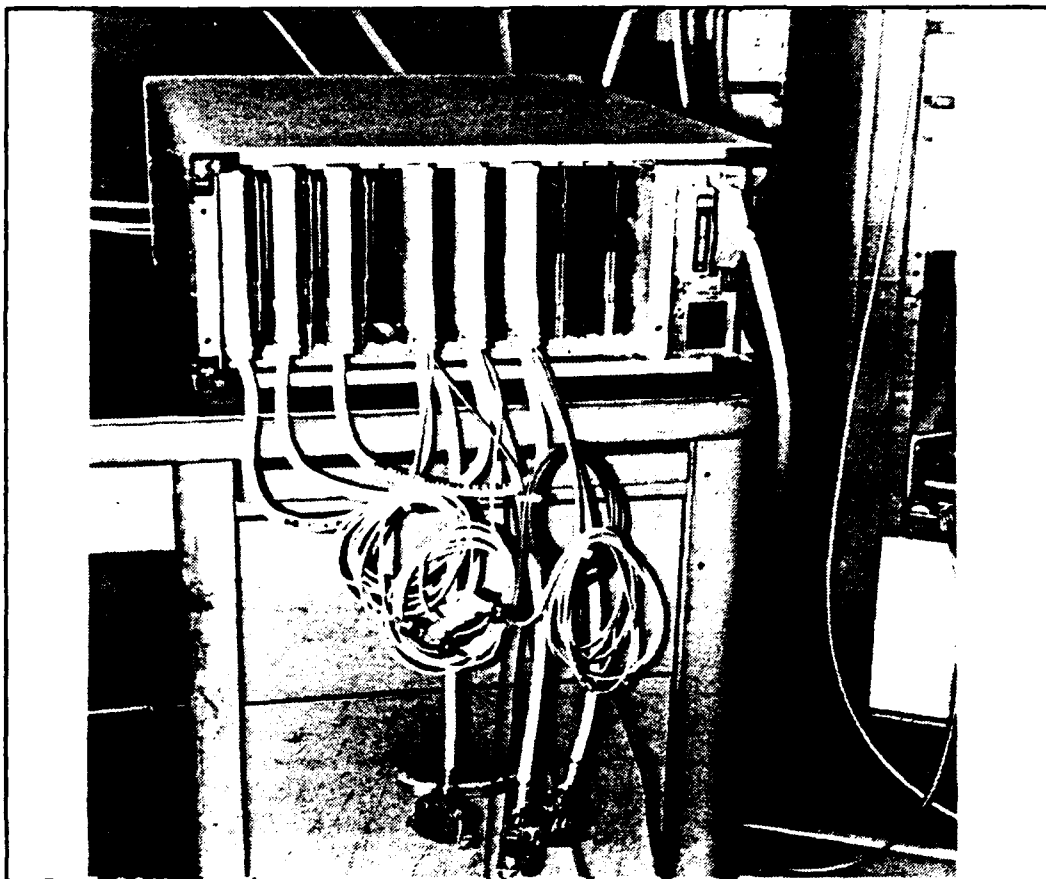


Figure 20 HP6944A Rear Panel and I/O Cards

set to handle input analog voltages between  $\pm 10$  volts [Ref. 19]. The A/D process provides a 12 bit resolution resulting in a 5 mV digital output voltage resolution.

The HP1417A Chaining Cable (Figure 21<sup>5</sup>) interfaces the A/D card with the Memory Card, Pacer Card and ZOC. The digital output voltage value from the A/D card is read to the Memory Card through the HP1417A cable. The Pacer Card's trigger signal and ZOC voltage signal are received by the A/D card through Chaining Cable input leads.

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<sup>5</sup> Figure 21 is in Ref. 19 as figure 2-2.

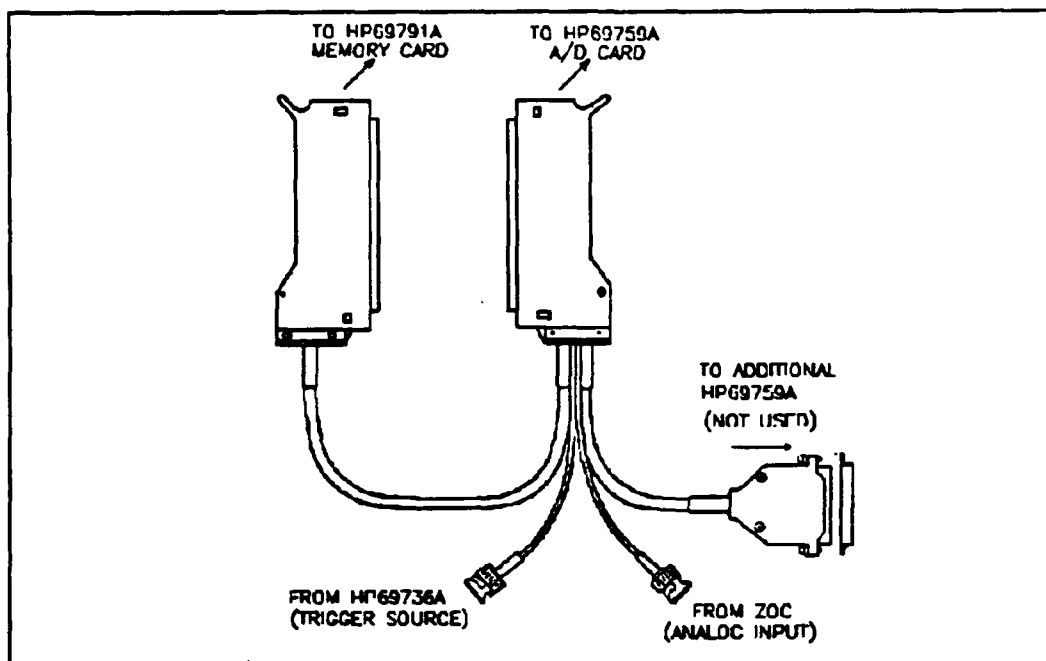


Figure 21 A/D-Memory Chaining Cable

## (2) Memory Card (HP69791A)

The Memory Card is a digital data storage device used here to store ZOC voltage values from the A/D card. Data are stored in 16-bit words and the storage capacity is 65,536 words of RAM [Ref 20]. Data words can be written into the RAM at rates of up to 800 KHz. The data are extracted from the RAM into the HP9000 RAM at rates of up to 30 KHz. The difference in data rates does not limit the ZOC-14 DAS process. The DAS program is designed to collect and store all raw pressure data on the Memory Card for each acquisition cycle before any data are transferred to the HP9000.

### (3) Counter/Totalizer Card (HP69775A)

The Counter Card is use in conjunction with the Timer/Pacer Card to count the number of events that occur during a specified data collection cycle. A trigger signal from the Timer/Pacer Card provides the signal pulse to step the Counter Card's integer "count-up" function. The Counter Card has two counting modes that count at rates of up to 1 Mhz [Ref. 15 and Ref. 21]. The mode used in the ZOC-14 DAS process counts from -32768 to 0. This capability allows 1023 samples per port of data, or 1023x32 events for a maximum of 32736 total data points per run.

The Counter Card provides the count value at the card's Edge Connector (Figure 22<sup>6</sup>) as an External Count Output. The output is a 16-bit number, which is the count value as the card is counting. Five of the sixteen bits (00 through 04) are used to drive the ZOC address value (bits A0-A4) through the Auxiliary I/O Logic Interface Device (Figure 6).

### (4) Timer/Pacer Card (HP69736A)

The Pacer Card is a square wave pulse generator with a programmable pulse width feature. The pulse width is programmable down to one micro second duration or a

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<sup>6</sup> Figure 22 is figure 3-5 in Ref. 21.



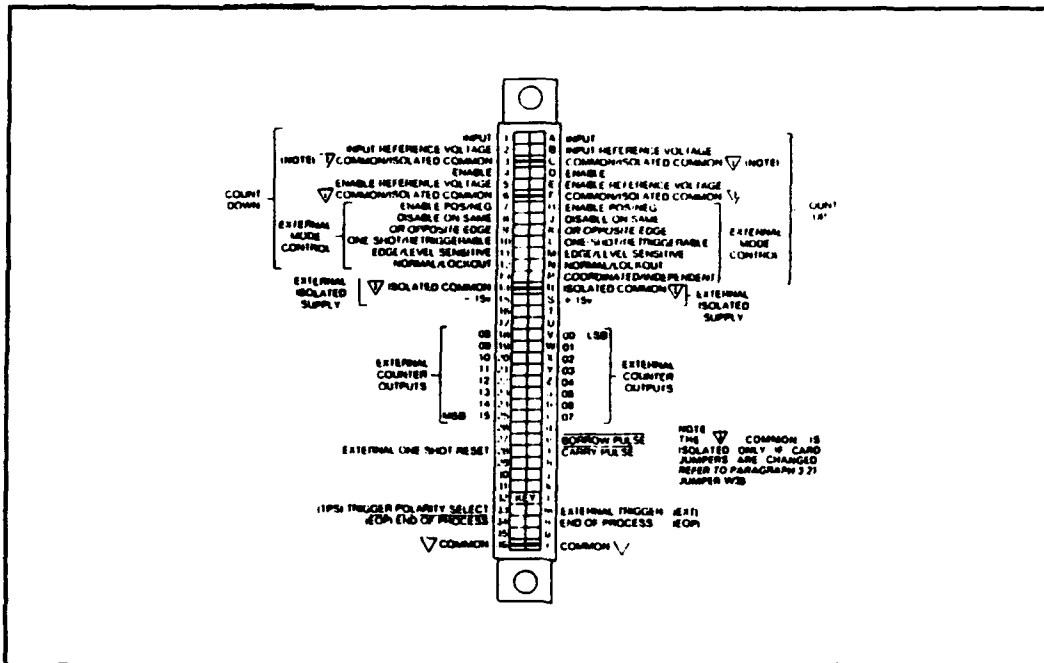


Figure 22 HP69775A Edge Connector

one MHz square wave<sup>7</sup>. The Pacer Card provides the trigger for the A/D Card and timing step trigger for the Counter Card.

### c. Multiprogrammer Configuration

#### (1) ZOC-14 Integration

The ZOC address format and the Counter Card's External Counter Output are the common link that interface the two devices. The Counter Card's count-up feature is used to control the ZOC port address. Starting at "-32", for which the binary equivalent is "00000" at the card edge, the card counts up to zero. Since 00000 is the binary number which is required to set the ZOC address to port number "1", the

<sup>7</sup> Refer to Ref. 15 and Ref. 22 for details on the HP69736A.

counting process steps the ZOC from port 1 to port 32. The count-up process realizes the following sequence:

decimal count	binary count	ZOC port address
-32	00000	01
-31	00001	02
-29	00010	03
	. . .	
-02	11110	31
-01	11111	32

Initiating the count-up from "-64" results in two scanning passes through the 32 port ZOC-14 since only the last five bits are identified in the ZOC address. Selection of the count-up value determines the number of scans through all the ZOC's ports.

The Counter Card's external output is set to 0.0-0.5 volt for "logic low" and to 2.0-5.0 volt for "logic high" [Ref. 21, page 1-2]. The ZOC address bits (A0-A4 in Figure 10) require an open collector Transistor-Transistor-Logic (TTL) driver to provide a ground "low" and an open "high" signal. The Auxiliary I/O Logic Interface Device (Figure 23) was designed to interface the HP69775A with the ZOC. Figure 24 is the electrical schematic of the device. The TTL 7404 is powered by a 5 volt regulator [Ref. 23]. The regulator receives 15 VDC power from the Counter Card's external edge connector.

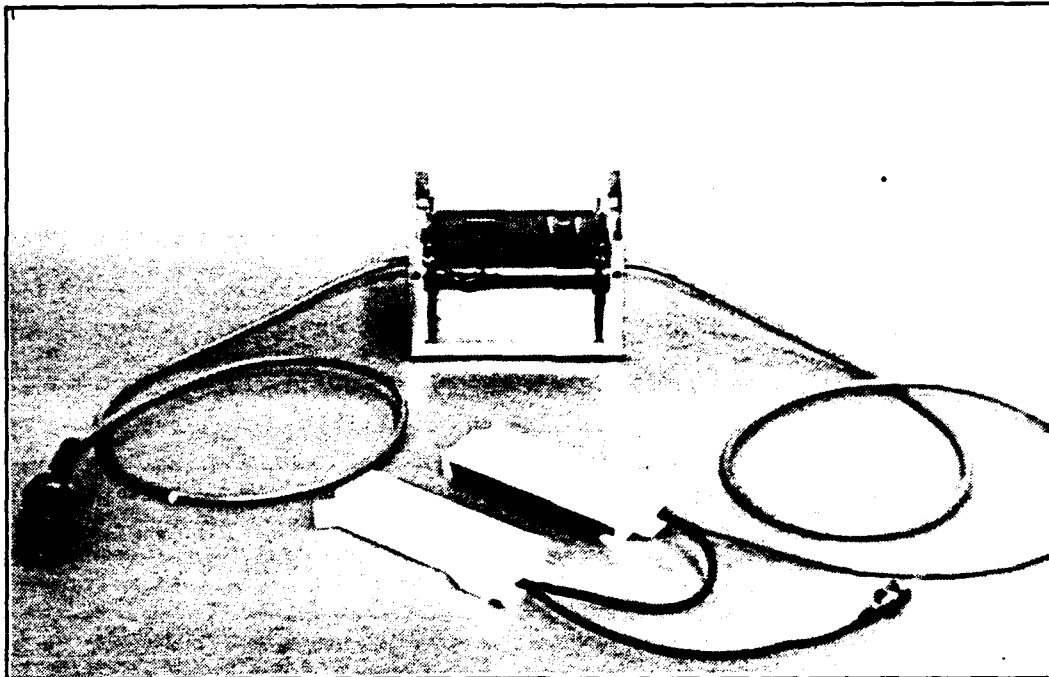


Figure 23 Auxiliary I/O Logic Interface Device

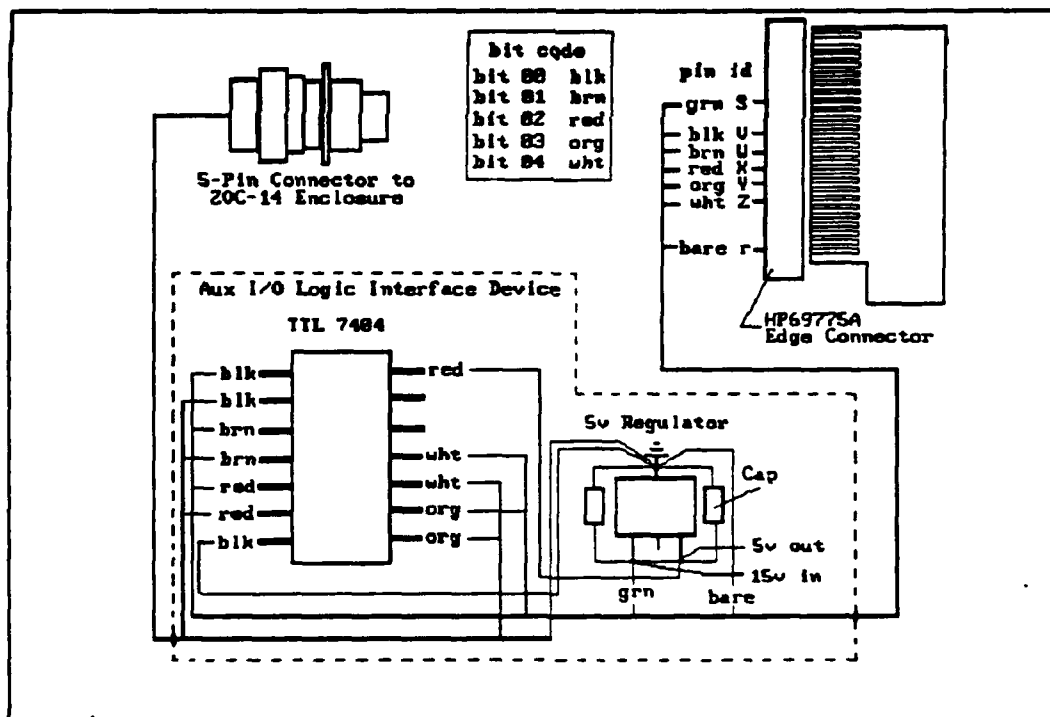


Figure 24 Auxiliary I/O Logic Interface Device Schematic

## (2) I/O Card Slot Configuration

The current configuration of the I/O cards and HP6944A provides the capability to collect pressure data from up to three ZOC-14 modules. Figure 25 illustrates the I/O card configuration and wiring to support the full ZOC-14 DAS.

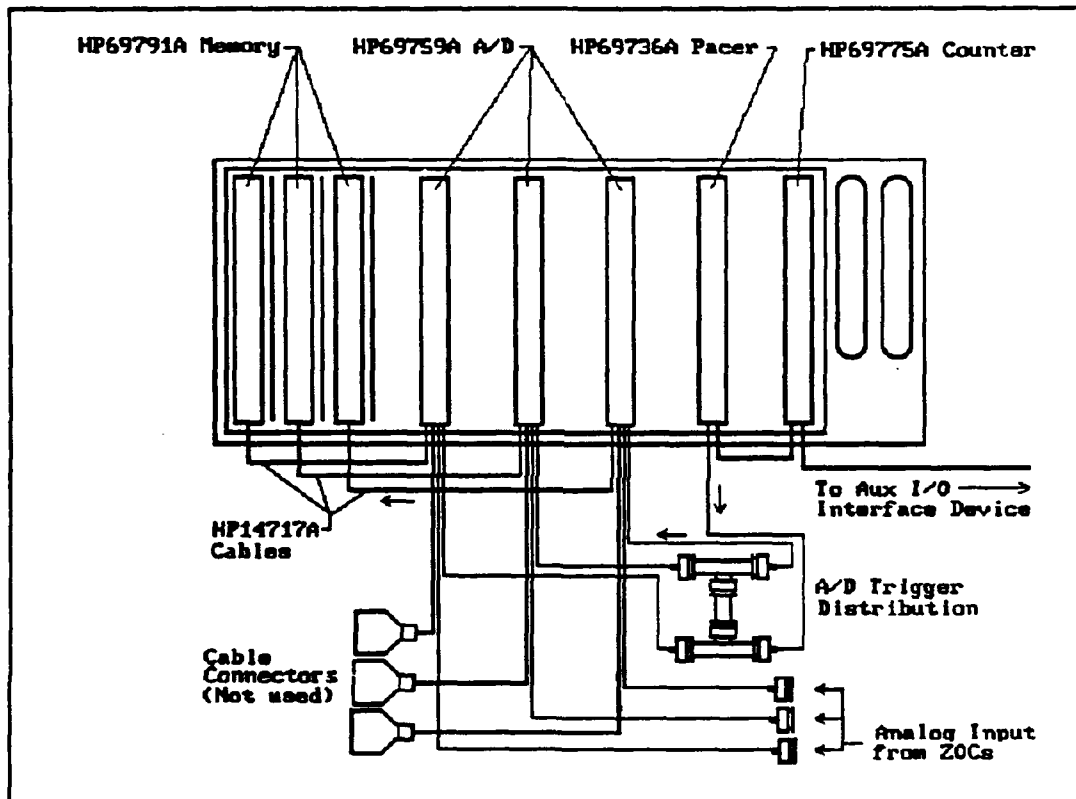


Figure 25 HP6944A I/O Card Configuration Diagram

Figure 26 shows the ZOC-14 DAS (not including the CALSYS2000) with one ZOC-14 module and all electrical lines connected.

The HP6944A has a power limitation determined by the built-in power supplies. Table I illustrates the HP6944A power supply availability and the I/O card power requirements. The HP6944A provides one 5 volt, one 12 volt and three 18 volt power supplies. The maximum amperage

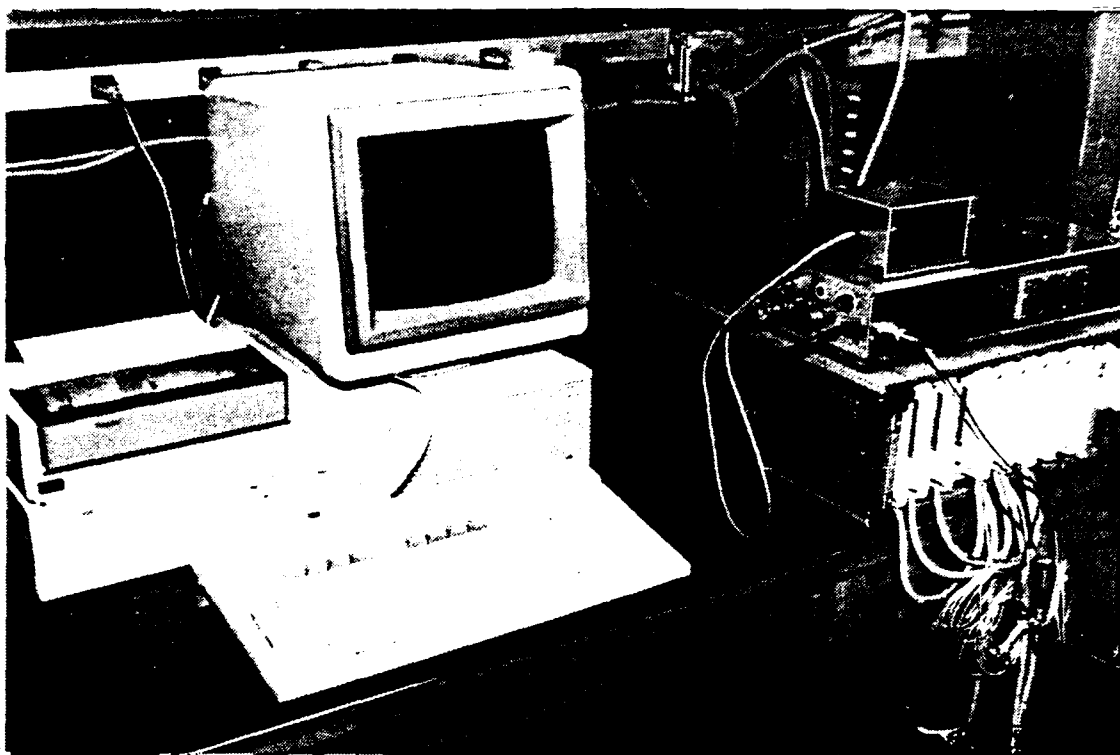


Figure 26 ZOC-14 Data Acquisition System (less CALSYS2000)

ratings are shown in Table I. The power required by the I/O cards are shown in amperes. The upper value in the table is the rating per card. For the HP69791A and HP69759A cards, the second value is the total rating for three cards of each type (which are required for three ZOC modules). The total amperage required for the three HP69759A cards exceeded the capacity of a single 18 volt power supply. Therefore, the first HP69759A card receives its power from the first 18 volt power supply. The second and third HP69759A cards receive their power from the second 18 volt power supply, from which they draw a total of 0.8 amperes. The HP69759A cards were set by the factory to draw power from the first 18 volt power

**Table I HP6944A Power Supply Allocation**

Device	Power Supplies				
HP6944A	+5V 16.0A (1)	+12V 2.0A (1)	-12V 2.0A (1)	+18V 0.85A (3)	-18V 0.4A (3)
Cards	Power Required				
HP69791A	3.6A 10.8A				
HP69759A	0.7A			(1) 0.4A	(1) 0.075A
HP69759A	0.7A			(2) 0.4A	(2) 0.075A
HP69759A	0.7A			(2) 0.4A	(2) 0.075A
HP69736A	0.75A				
HP69775A	0.75A	0.12A	0.15A	(1) 0.12A	(1) 0.150A
TOTAL	14.4A	0.12A	0.15A	(1) 0.52A (2) 0.80A	(1) 0.225A (2) 0.150A

supply. Access to the second 18 volt power supply required alterations to be made to the Power Supply Jumpers for the second and third HP69759A cards [Ref. 19, page 3-1].

## C. ZOC-14 DAS Software Description

### 1. General Overview

Hewlett Packard's BASIC 5.13 program language is utilized by the HP9000. Code is written in this language to communicate with the various data acquisition devices, process data and store the data to disk, and to output results on a printer or plotter. The HP6944A, a central component of the ZOC-14 DAS, is a relatively complex device which can perform numerous functions depending on how it is configured. The use of the HP6944A here required the generation of a unique software package in BASIC that integrated the HP6944A internal processor with the configuration of I/O cards selected here. The HP14753A Computer Aided Test (CAT) Programming Package provided the means to generate the software for that interface.

### 2. Data Acquisition Program

#### a. HP14753A CAT Program Package

The HP14753A CAT Programming Package (Figure 27) [Ref. 15] is software (and documentation) required to operate the HP6944A and the associated I/O cards. The programmer uses the Hewlett Packard provided skeleton CAT example program to develop a tailored application program to perform specific processes. The ZOC-14 DAS application program, was developed using the CAT Programming Package, to



Figure 27 HP14753A CAT Programming Package

perform ZOC data collection, reduction, and storage titled "SCAN\_ZOC\_05" (Appendix A, Figure A17).

The CAT programming package provides the capability of integrating selected I/O cards into a unique function that combines the cards' capabilities into one function. Two particular applications used here combined the A/D and Memory Cards into a "Buffer" function, and the Pacer and Counter Cards into a "Timer" function.

The Buffer function performs the task of collecting analog data at a collection rate controlled by an external trigger device, converts the analog data to digital format, and temporarily stores the data. The Buffer function allows the high speed data collection rate of 500 KHz, which is only limited by the A/D conversion rate. Figure 28 is a



schematic of the wiring that links the A/D and Memory Cards together through the HP1417A Chaining Cable (Figure 21).

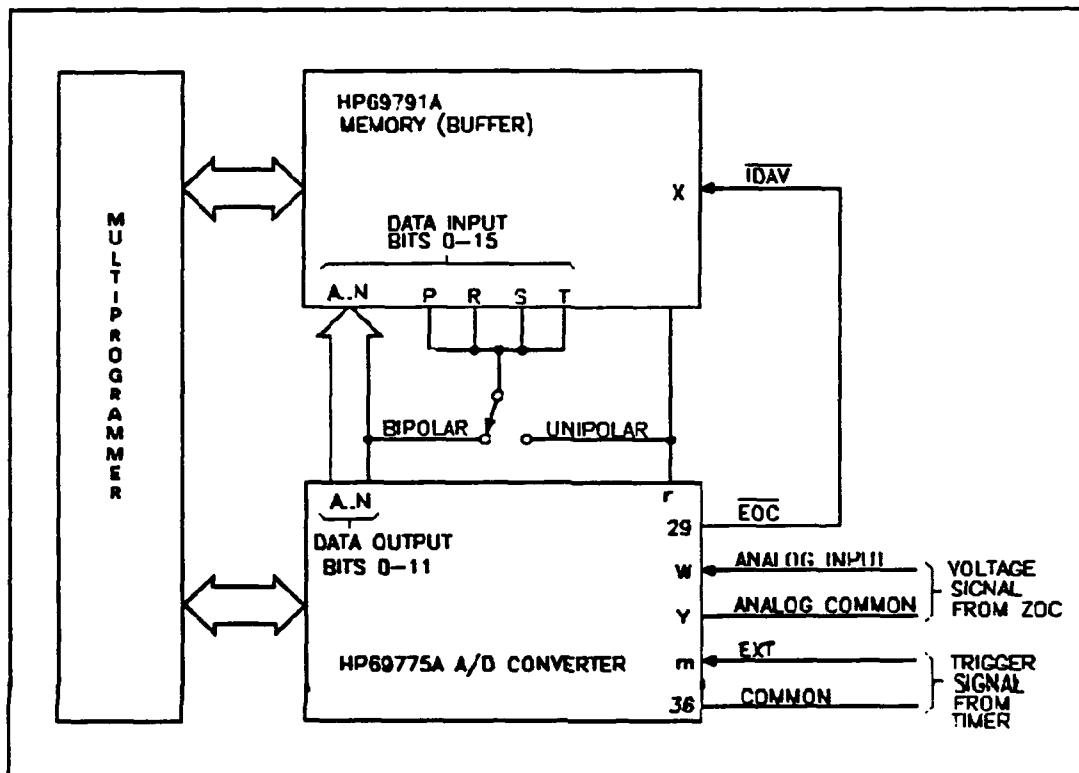
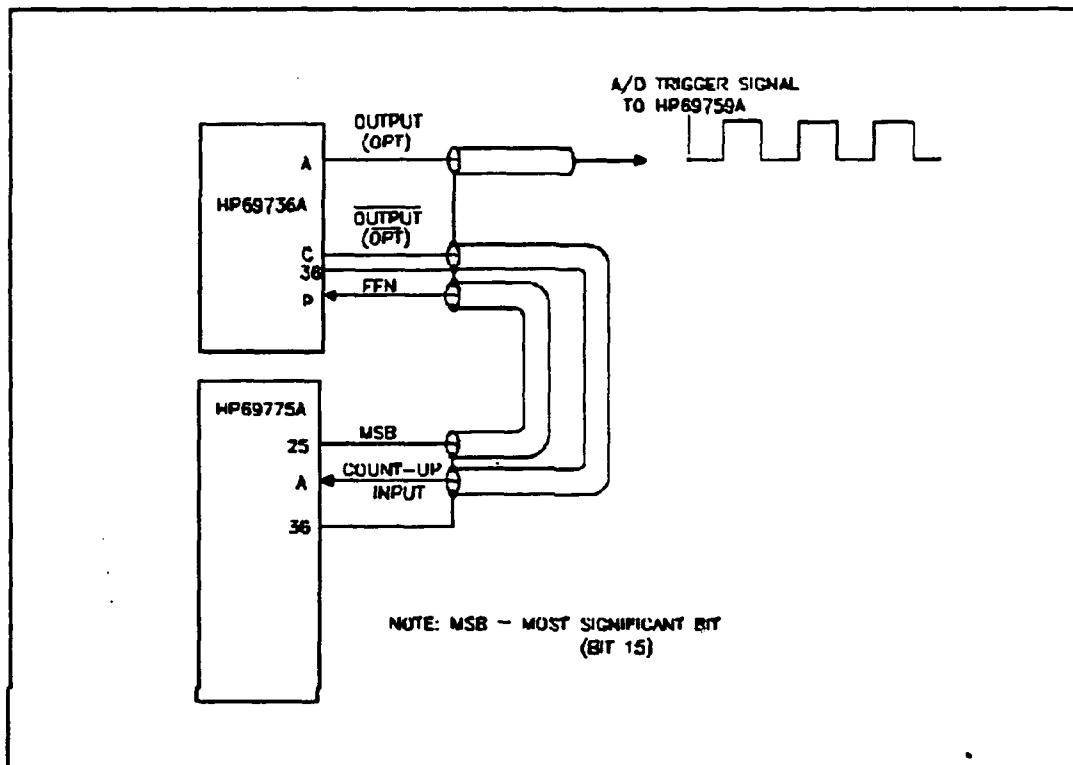


Figure 28 Buffered A/D Function Schematic

The Timer function provides a square wave trigger pulse of a specified pulse width and a specified number of repetitions. The pulse width determines the data collection rate. In the present application, the repetition number divided by 32, the number of ports on the ZOC-14, determines the number of scans the ZOCs undergo. The repetition number is therefore always a multiple of 32. Figure 29 is the schematic of the wiring that links the Counter and Pacer Cards together. The edge connectors and cables which were made to implement the wiring shown in Figure 29, can be seen in



**Figure 29 Timer Function Schematic**

Figure 23.

The CAT programming process requires identification of the installed I/O cards and their initial function settings through a user-specified "Configuration File". The file provides the flexibility of writing a general application program that works readily with various configurations of the HP6944A(s). Each configuration file is unique to each HP6944A hardware configuration<sup>8</sup>.

<sup>8</sup> The Configuration File must accurately reflect the HP6944A(s) I/O card configuration or a software error occurs.

Print-outs of the ZOC-14 DAS program Configuration File are listed in Figure A1<sup>9</sup>. [Note that the names listed in Figure A1 are variables used by the program SCAN\_ZOC\_05.]

#### b. DAS Program Design

##### (1) Program Design Features

The ZOC-14 DAS Program SCAN\_ZOC\_05 incorporated several design features intended to obtain a user-friendly data collection program. The program

- ◆ has full control of the ZOCs and CALSYS2000 as interfaced with the HP9000 and HP6944A
- ◆ utilizes the Zero Operate Calibrate principle for data collection from the ZOCs
- ◆ uses keyboard function keys to allow selection of various operations within the program
- ◆ creates and identifies data files automatically based on the type of data, date, and run number
- ◆ offers data file storage on hard and floppy disk drives.

##### (2) Data Files

Three different data files are used when acquiring data from each ZOC-14. Implementation of the Zero, Operate and Calibrate procedure required the data acquisition process to

- ◆ collect and store raw pressure data from the ZOCs

---

<sup>9</sup> Reference 15 provides details on Configuration File creation and alterations.

- ◆ collect and store calibration pressure data from the ZOCs and corresponding applied pressure standard data from the CALMOD 2000
- ◆ reduce the raw pressure data using calibration curves and store the reduced pressure data.

The program uses BDAT type files with Integer and Real number formats<sup>10</sup>. The raw data file is in Integer (2-byte) format, with each record corresponding to an output voltage value.

The calibration file uses a Real number (8-byte) format storing data from a 33 row by 11 column array<sup>11</sup>. Each row (1-32) corresponds to a ZOC Port. The Zero (0) row contains ZOC-specific parameters. Columns 4-10 in the Zero row contains pressure values measured by the CALMOD Pressure Standard for each of the seven calibration settings. Columns 4-10 (rows 1-32) contain voltages output by the ZOC for each of the calibration pressures applied through the CAL and REF manifolds. Columns 0-3 (rows 1-32) contain calibration curve fit coefficients for a third order polynomial. These coefficients are derived using the Least Squares numerical curve fit method using the recorded voltages (rows 1-32) plotted against the applied (standard) calibration pressures (row zero). Each row in the array corresponds to a record in the calibration data file consisting of 8x33 bytes.

---

<sup>10</sup> Refer to Ref. 6, chp 7, for details and advantages of BDAT format files compared to ASCII files.

<sup>11</sup> Refer to Figure A17, lines 2350 to 2440.

The reduced data file uses a Real number (8-byte) format, storing data from a n-row by 33 column array. Each row corresponds to one scan of a ZOC. The first column (0) stores the nth-scan number. Columns 1-32 correspond to the output of each ZOC port converted to pressure units (inches of mercury). Each array row occupies a record of 8x33 bytes in the reduced data file.

Figure 30 provides a sample listing of the data files created in acquiring data using three (3) ZOCs in one (1) acquisition cycle.

: ,700,0,1							
VOLUME LABEL: DATA							
FILE NAME	PRO	TYPE	REC/FILE	BYTE/REC	ADDRESS	DATE	TIME
ZW1205161		BDAT	97	2	592	16-May-92	14:54
ZW2205161		BDAT	97	2	594	16-May-92	14:54
ZW3205161		BDAT	97	2	596	16-May-92	14:54
ZC1205161		BDAT	33	88	598	16-May-92	14:55
ZC2205161		BDAT	33	88	611	16-May-92	14:55
ZC3205161		BDAT	33	88	624	16-May-92	14:55
ZR1205161		BDAT	3	264	637	16-May-92	14:55
ZR2205161		BDAT	3	264	642	16-May-92	14:55
ZR3205161		BDAT	3	264	647	16-May-92	14:55

Figure 30 ZOC-14 DAS Data File Listing

Each data file name uses the format,

<ZW><ZOC #><Date><Run #>

"ZW" identifies raw data files. ("ZC" identifies calibration data files, and "ZR" identifies reduced data files). The ZOC # is for ZOCs 1-3. The format for the date is YMMDD. The Run # has values 1-99. Hence, for example, the file ZR1205161 holds reduced data for ZOC #1 collected on May 16, 1992 during

Run #1. The REC/FILE column shows three records, identifying that three scans of data for the 32 ports were collected. The BYTE/REC column identifies 264 bytes for each record (scan), corresponding to the 8x33 bytes for the row format addressed in the previous paragraph.

### (3) Program Functional Flow Process

The program SCAN\_ZOC\_05 follows the functional flow process illustrated in Figure A2 through Figure A16 in Appendix A. The program relies on extensive use of subroutines to maintain program architectural simplicity through use of the CALL statement. The option to use one to three ZOCs requires only the repetitious use of the different subroutines.

Function keys are used for program control. The main program is segmented into blocks. Each block or set of blocks is initiated by a function key (ie. f1 through f8). The "GOTO Hold" statement executes a continuous loop sequence which is only interrupted by a function key selection, thus providing the mechanism for program control.

The storing of raw pressure data and calibration data onto the hard drive allows repeated data collection runs. The data reduction routine is function key selected and can be performed after each data collection run, or at any later time. The program prompts the user for data

file name information when data reduction is not selected immediately following a data collection run.

### c. DAS Program Use

#### (1) HP9000 Operation and Rudimentary Commands

The HP9000 is the controlling unit for the ZOC-14 DAS. Its operation is similar to that of a desk top computer system with no complex initialization or "boot-up" process.

The HP9000 has its own built-in boot-up routine as an integral part of BASIC [Ref. 4]. The boot-up process addresses the "SYSB51.HP-UX" file on the hard drive's root directory for loading various function drivers called "Binaries". Integration of the HP14753A CAT programming package in the present work required modification to the SYSB51 file to provide sufficient RAM space to operate the CAT programs<sup>12</sup>.

The boot-up process is initiated when power is applied to the HP9000. The CRT begins displaying a series of screens during the boot-up. With the modification which was made to the SYSB51 file, completion of the boot-up process now gives the screen display shown in Figure 31, which is generated by the AUTOST program file. This screen, referred

---

<sup>12</sup> Refer to Ref. 4, chp 5 and Ref. 15, pg. 1-5, for details on the SYSB51 file modifications.

to as the "Main Menu", provides a function key selection menu to access the operations available on the HP9000.

```

HP9000 Series 300 Computer Data Acquisition System.

Item:                                Select Function Key

Turbocharger Lab (*)                 F1
Transonic Compressor Lab (*)         F2
Turbine Design Programs (*)          F3
Multi-Programmer Operation (HP6944A) F4
Work directory (*)                   F5
Backup Files                         F6
HP9000 Program Listing and Information F7
Exit Menu                           F8

Note: Binaries required for HP14753A CAT program are loaded
      to operate the HP6944A Multi-programmer.
      Additional binaries are loaded with selection (*).

      If Error 2 occurs: Memory overflow; reboot system using
      SYSBOOT statement and reselect desired directory.

      User 1  Caps  Command
TURBO  COMPRESS DESIGN  HP14753A  WORK  BACKUP  PROGRAM EXIT
CHARGER LAB          CAT      DIR    LISTINGS MENU  *

```

Figure 31 HP9000 Initial CRT Screen Display

Selection of the "F8" function key clears the screen and places the user in the root directory. At any time when the term "idle" is displayed in the lower right corner of the CRT screen, there are no programs in execution, and the user can make keyboard command entries.

There are five essential, rudimentary commands that the user needs to know to use BASIC<sup>13</sup>. These commands are LOAD, RUN, CAT, MSI, and RE-S DRE. The LOAD command will load the program which is named between quotes into the HP9000 RAM. RUN will execute the program currently in RAM. CAT will

<sup>13</sup> It is recommended that the user reviews Ref. 13 and 14 for an operational understanding of BASIC.



list to the CRT screen all the files on the current storage drive and directory. MSI ("MASS STORAGE IS") will select a directory and/or drive to be what is named between quotes. The RE-STORE command copies the program in the RAM to the file on the currently named MSI. Caution must be applied when using the RE-STORE command. This command will write over any previously existing program with the same name, resulting in the loss of the previous program.

Return to the Main Menu is possible from any directory on the hard drive. Located on the root directory of the hard drive is a program called "RETURN\_MAIN". Load the program by typing the following commands:

- ◆ LOAD "/RETURN\_MAIN", followed by the <Enter> key
- ◆ RUN, followed by the <Enter> key

The "/" character identifies the root directory. The above two steps apply for loading and executing any program.

## (2) Operating the ZOC-14 DAS Program

The ZOC-14 DAS Program uses function keys and selective keyboard data entries. The following steps should be followed to operate the ZOC-14 DAS.

1. Main Menu: Depress function key F4 (Figure 31) to call-up the HP Multi-programmer Operating Menu.
2. HP6944A Operation Menu: Depress function key F1 to call-up the ZOC-14 Modules Menu.

3. Zoc Electronic Pressure Module Operation Menu:  
Figure 32 is displayed.

Zoc Electronic Pressure Module Operation Menu			
Item:	Select Function Key		
Scan 1-3 ZOC-14 Modules (32 ports ea)	F1		
Read reduced data from ZOC-14 module	F2		
Plot reduced data from ZOC-14 module	F3		
Read CALSYS 2000 calibration pressures	F4		
Read tabulated calibration data	F5		
Plot Calibration data	F6		
HP6944A Main Menu	F7		
Exit Menu	F8		
SCAN 1-3 READ ZOC PLOT ZOC READ	User 1 Caps Command		
ZOCS DATA DATA CALSYS20	TABULATE PLOT CAL HP6944A EXIT		
	CAL DATA DATA MENU MENU		*

**Figure 32 Zoc Electronic Pressure Module Operation Menu**

4. Check: Ensure that the CALSYS2000, ZOC Enclosure and HP6944A are properly connected and energized.
5. Check: Ensure that the nitrogen gas supply is connected to the CALSYS2000 and about 90 psi is set on the regulator.
6. CALSYS2000 Regulators: Set the High, Medium, and Low Pressure regulators on the CALSYS2000. The three pressure values should be evenly distributed within the span of the ZOC's positive pressure rated range. Precise settings are not critical. Since 50 psid and 15 psid ZOCs are used presently, set the regulators between 0-30.6 inches of mercury to avoid over pressurizing the 15 psid ZOCs.
7. CALSYS2000 Verification: Select function key F4 (Figure 32) to cycle the CALSYS2000 and verify the pressure settings. (Note: This should be done whenever the CALSYS2000 is first energized to clear the RS-232C of noise). Completion of this step returns the HP9000 to the ZOC operation menu.

8. Load SCAN\_ZOC\_05: Select function key F1 (SCAN ZOCS) from the ZOC operation menu to initiate ZOC scanning program SCAN\_ZOC\_05.
9. Introduction: A series of screen displays occur while SCAN\_ZOC\_05 is loading. The "Introduction" screen (Figure 33) is displayed indicating that the program is waiting for a function key input.

```

Introduction. Program SCAN_ZOC_05:

- Scans 1-3 Zoc-14 Modules simultaneously (32 pressure sensing ports each).
- Uses Zero Operate Calibrate (ZOC) principal:
  - Collects raw pressure data (Zero Operate)
  - Collects calibration data (Calibrate)
  - Reduces and stores data on selected hard or floppy drive.
- CALSYS2000 Calibration Module used for the reference pressure standard.
- Raw pressure data reduced using calibration data from CALSYS2000
  and Zocs in the calibration mode.

Input variables: Hard and Floppy drive for data storage
                  Sample frequency per port (1-50,000 Hz)
                  Samples per Port (1-1021)
                  Number of Zocs and their capacity

Output files:     Raw data =>   ZN(Zoc#)(Date Y#M#D)(Run#)
                  Calibration => ZC(Zoc#)(Date Y#M#D)(Run#)
                  Reduced data => ZR(Zoc#)(Date Y#M#D)(Run#)

Select F2 key for Key Menu, F3 for system inputs, or F6 for data reduction.

Intro  Key      Set-up  Data      Collect  Reduce  User 1  Caps  Command
Menu   Menu                                     List     Exit
                                     Copy

```

Figure 33 SCAN\_ZOC\_05 Introduction Screen

10. Set-up Selection: Select function key F3 (Set-up) to initialize the program. The "Set-up" screen will be displayed. (Note, selection of F4 or F5 at this time results in an error message and asks for re-selection.)
11. Set-up Inputs: The user will be prompted for the designated data storage drive (select :,700,0,1 if equipped)<sup>14</sup>, data acquisition rate, the number of

<sup>14</sup> The program operates on multi-partitioned hard drives. TPL's HP9153C Disk Drive has two partitions. Drive :,700 is the main drive and is in HFS format with 10 Mbytes of space. Drive :,700,0,1 is the second "DATA" drive and is in LIF format with 30 Mbytes of space. LIF format has faster data transfer rates.

samples per port (scans) of data to be taken, and the number of ZOCs to be used. For each ZOC, the user will be prompted for the CALMOD to be assigned to the ZOC. Currently only one CALMOD is installed. Enter 1 for all three ZOCs. When two CALMODs are installed, enter 1 or 2 to the applicable ZOC according to the CALMOD regulator settings.

12. **Set-up Display:** The System Set-up screen (Figure 34) is updated as entries are made. The program searches the data drive for data files and creates the next sequential data file name for the current date.

```

System Set-up.

Data acquisition rate:          10000 Hz
Number of samples per port:    3
Number of Zocs to be scanned:  3
Total raw data acquisition time: .0093 sec.
Total calibration data acquisition time: 10.5155 sec.

Data storage disc =>: ,700,0,1
Data will be stored in the following files beginning with Run # 1

Raw data file:      ZW1204291
Calibration data file: ZC1204291
Reduced data file:  ZR1204291

Raw data file:      ZW2204291
Calibration data file: ZC2204291
Reduced data file:  ZR2204291

Raw data file:      ZW3204291
Calibration data file: ZC3204291
Reduced data file:  ZR3204291

```

**Figure 34 SCAN\_ZOC\_05 System Set-up Screen**

13. **Data Collection Preparations:** Select function key F4 (Data Preps) for data collection preparations (Figure 35).
14. **Collect Data:** Select function key F5 (Collect data) to begin data collection. The CRT will display the results of the collection as illustrated in Figure 36.
15. **Data Reduction:** To reduce data, select function key F6 (Reduce Data). To make changes to the Set-up, select function key F3. To conduct another raw data collection run, select function key F4. To exit the

program, select function key F8. Selection of F6 results in the display illustrated in Figure 37.

16. List/Copy Files: Selection of function key F7 (List Files) will list all current data files on the storage drive as illustrated in Figure 38. The user

Data Collection Preparation.

Check list:

- HiScan CALSYS2000 on-line
- Calibrator supply line valve is OPEN (on back of Hiscan)
- CALSYS2000 (Nitrogen) pressure source at 90 psi

Select F5 to start data aquisition

						User 1	Caps	Command
Intro	Key	Set-up	Data	Collect	Reduce	List	Exit	
	Menu		Preps	Data	Data	Files		*

Figure 35 SCAN\_ZOC\_05 Data Preparations Screen

will be prompted if he wants to store all the listed files to the floppy drive :,700,1. Selection of "Yes" results in the over-writing of the old files with the same file name.

17. Exit: Select function key F8 (Exit) to exit the SCAN\_ZOC\_05 program and return to the ZOC operation menu (Figure 32).

### 3. Data Analysis and Auxiliary ZOC-14 Programs

#### a. Utility Programs

The ZOC operation menu (Figure 32) displays several utility programs which were written for system analysis and

```

Collecting raw pressure data.

Raw data collection complete.

Raw pressure data: Run# 1 , Zoc# 1 , storage drive file ZW1204291:,:700,0,1
Raw pressure data: Run# 1 , Zoc# 2 , storage drive file ZW2204291:,:700,0,1
Raw pressure data: Run# 1 , Zoc# 3 , storage drive file ZW3204291:,:700,0,1

Collecting calibration data.
Calibration data: Run# 1 , Zoc# 1 , storage drive file ZC1204291:,:700,0,1
Calibration data: Run# 1 , Zoc# 2 , storage drive file ZC2204291:,:700,0,1
Calibration data: Run# 1 , Zoc# 3 , storage drive file ZC3204291:,:700,0,1

Calibration data collection complete.

*** Secure Calibrator pressure valve to conserve Nitrogen ***

CALSYS2000 Calibration modes and pressures (in Hg):

Mode      Zoc #1      Zoc #2      Zoc #3
NH        -30.1544    -30.1544    -30.1544
NM        -17.9976    -17.9976    -17.9976
NL        -7.3819     -7.3819     -7.3819
ZO         .0034       .0034       .0034
PL         7.4005     7.4005     7.4005
PM        18.0194    18.0194    18.0194
PH        30.2072    30.2072    30.2072

Select F4 for another data run, or F8 to reduce data

Intro      Key      Set-up      Data      Collect      Reduce      User 1      Caps      Command
           Menu                                Data      Data      List      Exit
                                Data      Data      Files      *

```

Figure 36 SCAN\_ZOC\_05 Data Collection Screen

data display. These utility programs, listed in Appendix A, are tailored for use with the SCAN\_ZOC\_05 data file formats<sup>15</sup>.

#### b. ZOC-14 Utility Program Application Examples

An air source regulated to 30.0 inches of mercury gauge was used to verify the acquisition hardware and software. Application programs were written to analyse the results.

<sup>15</sup> Data files created from previous versions of the SCAN ZOC programs listed in Appendix B are not compatible with the listed utility programs.

```

Calibration and Raw data reduction and storage.

Current files on storage disc : ,700,0,1 for date 20429

ZW1204291  ZC1204291  -
ZW2204291  ZC2204291  -
ZW3204291  ZC3204291  -

Data reduction: Run# 1 , Zoc# 1
Calibration data reduced and transferred to ZC1204291
Raw data reduced and transferred to ZR1204291

Data reduction: Run# 1 , Zoc# 2
Calibration data reduced and transferred to ZC2204291
Raw data reduced and transferred to ZR2204291

Data reduction: Run# 1 , Zoc# 3
Calibration data reduced and transferred to ZC3204291
Raw data reduced and transferred to ZR3204291

Select F3 reinitialize set-up for data collection, or F8 to Exit

Intro      Key      Set-up  Data      Collect  Reduce  List      Command
Menu       Menu              Preps     Data      Data     Files     Exit      *

```

Figure 37 SCAN\_ZOC\_05 Data Reduction Screen

```

List Raw, Calibration and Reduced data files.

Data storage drive name => : ,700,0,1

Current files on storage disc for date 20429

ZW1204291  ZC1204291  ZR1204291
ZW2204291  ZC2204291  ZR2204291
ZW3204291  ZC3204291  ZR3204291

Select F2 to return to menu, or F8 to Exit

Intro      Key      Set-up  Data      Collect  Reduce  List      Command
Menu       Menu              Preps     Data      Data     Files     Exit      *

```

Figure 38 SCAN\_ZOC\_05 List Files Screen

The program "READ\_ZOC" (Figure A18) is selected by function key F2 (READ DATA). The program's results are illustrated in Figure 39 for ZOC #3 (rated at 15 psid). The

```

Period between samples (sec): .0001
Sample collection rate (Hz): 10000
Number of samples per port: 3
Length of data run (sec): .0093

Data Tabulation for Port # 1 from file: ZR3204291

Sample      Time (sec)      Pressure (Hg.)
1           0.00000      29.62346
2           .00320      29.58425
3           .00640      29.62346

Data Tabulation for Port # 2 from file: ZR3204291

Sample      Time (sec)      Pressure (Hg.)
1           .00010      29.62771
2           .00330      29.62771
3           .00650      29.62771

Enter port number for data (0=Exit):

User 1  Caps  Command
EDIT   Continue  RUN   SCRATCH  LOAD ""  LOAD BIN LIST BIN RE-STORE
      ""          ""          ""          *

```

Figure 39 READ\_ZOC Data Results

displayed pressure is the reduced pressure value calculated from the SCAN\_ZOC\_05 program. The output pressure is derived using the recorded transducer output voltage and the curve fitted to the calibration data for the identified port. The output values are seen to be within 1.3% of the applied pressure.

The program "PLOT\_DATA" (Figure A19) is selected by function key F3 (PLOT DATA). The results from ZOC #3 are displayed in Figure 40 and Figure 41.

The program "CAL\_READ\_PR1" (Figure A20) is selected by function key F4 (READ CALSYS20). The results are displayed in Figure 42.

The program "TABULATE\_ZOC" (Figure A21) is selected by function key F5 (TABULATE CAL DAT). This program displays the



```

Program plots reduced data from file ZR3204291

Statistics for Zoc # 3

    Period between samples (msec): .1
    Sample collection rate (Hz): 10000
    Number of samples per port: 3
    Length of data run (msec): 9.5

Data point can be plotted as a continuous line, or squares.

Note: Wait for symbol '*' in lower right corner of CRT to change
      to a '-' before pressing <Shift><Dump Graph>

EDIT   Continue   RUN   SCRATCH   LOAD ""   LOAD BIN LIST BIN RE-STORE
                                ""          ""          *
                                User 1 Caps Command

```

Figure 40 PLOT\_DATA Alpha Screen Display

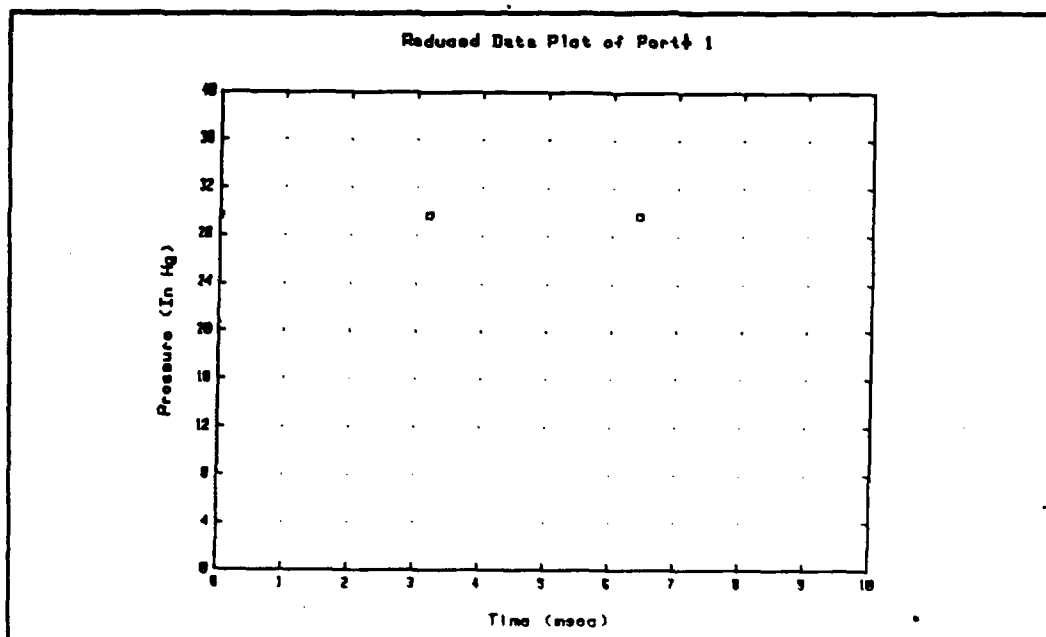


Figure 41 PLOT\_DATA Graphic Screen Display

first three reduced data samples of selected ports, and the associated calibration data for each selected port. Figure 43 displays the results for ZOC #3.

Program: CAL\_READ\_PRI

This program sequentially sets the CAL2000 calibration modes and reads the corresponding internal Pressure Standard for that mode.

PH	Positive high range pressure to CAL(+)
PM	Positive mid range pressure to CAL(+)
PL	Positive low range pressure to CAL(+)
ZO	CAL(+) & REF(-) connected together
NL	Negative low range pressure to REF(-)
NM	Negative mid range pressure to REF(-)
NH	Negative high range pressure to REF(-)

CAL2000: Calibration modes and pressures.

Mode	Pressure (in Hg)
NH	30.1606
NM	17.9945
NL	7.3788
ZO	.0034
PL	7.3912
PM	18.0194
PH	30.2072

Figure 42 CAL\_READ\_PRI Results

Program tabulates Zoc pressures and calibration data from the SCAN\_ZOC\_03 program.

Reduced Data Tabulation at a sample rate of 10000 Hz

Port	Sample 1	Sample 2	Sample 3
1	29.623	29.564	29.623
2	29.628	29.628	29.628
3	-.414	-.414	-.351
4	-.495	-.425	-.425

Calibration Data Tabulation for Zoc# 3

Pressure voltage readings:

Port	NH	NM	NL	ZO	PL	PM	PH
0	-30.154	-17.998	-7.382	.003	7.401	18.019	30.207
1	-2.194	-1.310	-.321	.040	.723	1.688	2.704
2	-2.594	-1.689	-.850	-.276	.450	1.478	2.549
3	-1.853	-1.018	-.250	.272	.909	1.820	2.770
4	-1.770	-1.036	-.362	.101	.673	1.485	2.320

Calibration polynomial coefficients for Zoc# 3

Port	A0	A1	A2	A3
1	-1.00116186204	11.8955586742	-.435562698234	.106534210924
2	2.45870376346	11.1095966035	-.349715337703	.0940454333066
3	-3.96668335674	12.8254266665	-.523187753647	.119575469008
4	-1.98202140047	14.2260022322	-.645728820628	.20262038018

Figure 43 TABULATE\_ZOC Results

The program "LS\_PLOT" (Figure A22) is selected by function key F6 (PLOT CAL DATA). Figure 44 displays the calibration data with voltage verses CALMOD calibration

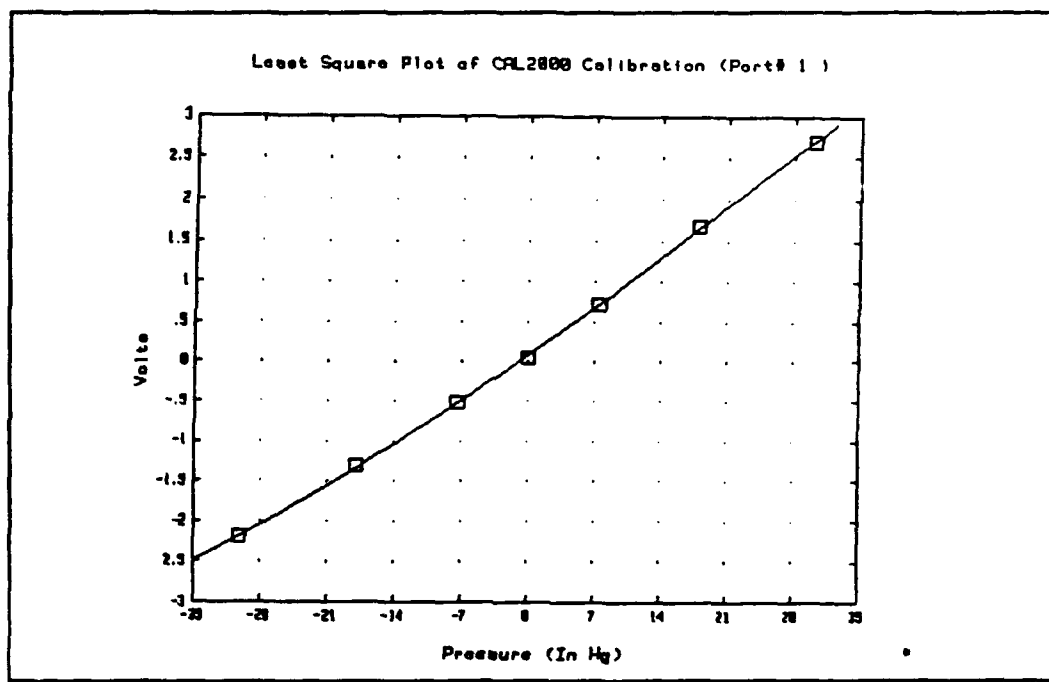


Figure 44 LS\_PLOT Graphic Results

pressure (squares), and the curve fitted to the collected data by the least squares method (continuous line). The results are from port #1 on ZOC #3.

### III. DISCUSSION

#### A. Upgraded Capabilities

The ZOC-14 DAS provides the capability to perform fully automatic high-speed pressure data acquisition, data storage and reduction. For the Gas Dynamics Laboratory (GDL), this upgraded capability allows very short run-times in the transonic and supersonic wind tunnels, resulting in greatly reduced electrical power consumption by the laboratories air compressors and the elimination of delays between wind tunnel tests. Additionally, wind tunnel models will have a longer useful life. The shorter run times will reduce model erosion and the net effect is a reduced cost to operate the wind tunnels and to maintain models.

The HP9000 now serves as the controller for the DAS's in each of the three laboratories comprising TPL and GDL. Each DAS includes Hewlett Packard HP-IB compatible instruments and the HG-78K Scanivalve Controller. Low speed pressure data acquisition, using the HG-78K to operate the Scanivalve rotary port pressure sensing unit, is retained. However, for turbomachinery measurements, phase-lock data acquisition using TPL's Digital Programmable Timing Device (or PACER), can not yet be performed using the HP9000 to replace the HP1000 [Ref. 24]. TPL's PACER is electrically hard-wired into the HP1000

as an I/O device. However, the integration of the HP9000 and HP6944A, as demonstrated in the ZOC-14 DAS, is known to provide the interface capability to operate the PACER.

Temperature and low-speed pressure measurement data acquisition and processing using the HP9000 has been demonstrated in turbocharger performance mapping laboratories and transonic wind tunnel thesis research [Ref. 25]<sup>16</sup>. The HP9000 was shown to provide improved data storage handling and display capabilities (over the HP1000 system) using the HP9153 series hard/floppy disk drive and HP7475A plotter.

Development of the ZOC-14 DAS served to identify the programming and integration requirements, and the capabilities of the HP9000 and HP6944A as a subsystem. The HP9000/HP6944A as a controller and data acquisition sub-system provides to TPL and GDL the potential for extension in several prospective applications.

#### **B. ZOC-14 DAS Outstanding Issues**

The ZOC-14 DAS development is not fully complete. Several hardware, software, and performance issues need to be resolved, namely;

- ◆ **Hardware:** The CALSYS2000 is using only one CALMOD to provide calibration pressures for a specific ZOC operating range. A second CALMOD is required.

---

<sup>16</sup> Appendix D, Figures D3-D6 are HP9000 controlled Turbocharger Performance Mapping and data display programs.

- ◆ Hardware: It was not possible to set the "PURGE" mode to clear pressure sensing lines using nitrogen gas supply.
- ◆ Software: SCAN\_ZOC\_05 uses a "set" 1.5 sec time delay to account for calibration pressure stabilization during the calibration process, vice a technique to monitor the calibration pressure and digitize when found to be stable.
- ◆ Performance: The maximum data sampling rate achievable with the ZOC modules needs to be verified.
- ◆ Performance: A data error analysis needs to be carried out.
- ◆ Performance: The calibration of the CALMOD Pressure Standard needs to be verified.

Some elaboration of each of these issues follows.

The use of the present one CALMOD results in only the 15 psid ZOC being calibrated over its full pressure range when 15 psid and 50 psid ZOCs are used in the DAS. The 50 psid ZOC must be used without the 15 psid ZOCs if they are to be calibrated and used over their full range. This would reduce the pressure data measurement availability from 96 (3x32) to 32 ports. Installation of a second CALMOD would allow independent calibration of the 15 psid and 50 psid ZOC modules. The program SCAN\_ZOC\_05 incorporates the steps to use two CALMODs, and requires no modifications.

The PURGE mode is set by providing control gas through both the Px and CAL control lines as illustrated in Figure 8<sup>17</sup>. Currently, the required control gas pressure is not provided by the PSC when the appropriate command is sent from

---

<sup>17</sup> Refer to Ref. 17, dwg 17750, PNEUMATIC DIAGRAM OF PSC.

the HP9000 to the CALMOD. The commands to set the PURGE mode are "aEC 8 Y" followed by "aEC 10 N" to set the solenoids in the PSC.

The calibration process requires a stabilization time delay to elapse between the setting of a calibration mode and the sampling of the calibration pressure by the Pressure Standard. The best method to determine the required time delay is to continuously sample the calibration pressure until the pressure stabilizes, then record the calibration pressure. The program SCAN\_ZOC\_05 uses an empirically derived 1.5 sec "wait period" between the calibration mode selections and the pressure sampling. This time value was determined using a modified CAL\_READ\_PR1 program, stopwatch and oscilloscope. CAL\_READ\_PR1 was modified with a PAUSE statement to allow observation of the ZOC voltage signal on the oscilloscope. When the signal appeared to stabilize on the oscilloscope, the CONTINUE key (F2) was depressed to sample the pressure and select the next mode. The times for six complete mode selections were recorded. The average time was found to be 1.34 seconds between depressions of the CONTINUE key. The value of 1.5 seconds was selected as a conservative value to use for the time delay.

The maximum sample data collection rate has not yet been realized with the ZOC-14 DAS. Preliminary observations revealed a random fall-off in pressure values when the "input" data sampling rate was greater than 50 KHz. A more careful

analysis of the sampling rate is required to validate the current 50 KHz value and to determine the maximum data sampling rate.

An error analysis of the ZOC-14 DAS is required to determine the accuracy of the data collection and reduction process. The HP67959A A/D Cards have a documented resolution of five milli-volts for their factory set configuration as installed in the HP6944A. The Pressure Standard mounted in the CALMOD has accuracy specifications documented in Reference 17. The ZOCs have measurement accuracy specifications documented in Reference 16. The numerical Least-Squares curve fitting routine introduces a so-far unspecified uncertainty. The reduced pressure readings provided in Figure 39 compared to the 30.0 inches of mercury source pressure, provide only a single example of the pressure measurement uncertainty given by the DAS<sup>18</sup>. Derivation of the overall system uncertainty needs careful attention.

The Pressure Standard's calibration has not been verified since it's delivery. Calibration verification is essential prior to accepting pressure measurement data. Accordingly, the CALMOD calibration coefficients, derived from the calibration verification, need to be changed on the CALMOD

---

<sup>18</sup> Uncertainty in the source pressure of 30.0 inches of mercury as measured by the TPL Calibration Pressure Manometer needs to be considered in the uncertainty analysis.



EPROM. Reference 17 provides the details to conduct Pressure Standard calibration and coefficient changes on the EPROM.

### C. Potential Extensions and other Applications

The HP9000/HP6944A subsystem provides the hardware features necessary to integrate computer control of experiments with the data acquisition process. Three immediate applications using the HP9000/HP6944A are identified here:

- ◆ The TPL PACER can be interfaced with the HP9000/HP6944A to provide phase-locked data acquisition capability<sup>19</sup>.
- ◆ Kulite pressure probe measurements can be acquired using the analog signal from the conditioning amplifier. The signal would be routed directly to the Buffer A/D Function input connector, using the Timer Function to set the data collection rate and number of samples.
- ◆ GDL's transonic and supersonic wind tunnels can be operated with fully automated data acquisition and experiment control systems. The tunnel's manual back-pressure valve, and electro-servo controlled translating survey probe can be operated by the HP9000/HP6944A to give fully automated control.

---

<sup>19</sup> Preliminary TPL PACER interfacing techniques have been examined but not yet documented.

#### IV. CONCLUSIONS

The DAS upgrade and extension which is reported here has included the adoption of the HP9000 as a controller for existing HP-IB compatible DAS instrumentation, the generation of acquisition and reduction software for the existing system, and the development of a new high-speed pressure data acquisition capability. The new high-speed system involved an integration of the HP9000 with the HP6944A Multiprogrammer and with Scanivalves's ZOC-14 and CALSYS2000 systems. In the present account, emphasis has been placed on reporting the development of the ZOC-14 DAS. The hardware and software for the system have been successfully demonstrated. It has been shown that the use of the system in the Gas Dynamics Laboratory can reduce wind tunnel test times by a factor of 20.

Six issues concerning the present hardware and software have been identified as needing to be resolved, and immediate applications of the HP9000/HP6944A system to Kulite and Phase-Locked data acquisition, probe survey and tunnel condition control, have been identified. The programs and experience reported in the present document can serve to guide these extensions.

The key to developing the capabilities resident in the HP9000/HP6944A system is a thorough familiarity with HP BASIC

and HP14753A CAT programming. Therefore, the recommendation is made that formal instruction in this language and programming techniques be provided before the recommended extensions of the system are attempted.

## APPENDIX A. ZOC-14 PROGRAMS

Appendix A is a compilation of pertinent information and programs used to operate the ZOC-14 DAS.

Figure A1 is the ZOC-14 DAS program configuration file, "ZOC\_CONFIG\_05", print-out for the I/O Cards installed in the HP6944A. The print-out is produced using the CAT program "DOCUMENT". The DOCUMENT program is located on the "/HP6944A" directory (Figure D1). ZOC\_CONFIG\_05 is a BDAT file located in the /HP6944A directory.

Figures A2 through A16 are parts of the SCAN\_ZOC\_05 program flow chart. Figure A17 is the SCAN\_ZOC\_05 program listing with program-specific remarks anotated after the "!" character.

Figures A18 through A22 are ZOC-14 DAS utility programs located on the /HP6944A directory.

Figure A23 is the program used to display the ZOC operation menu, and define the function keys to provide menu item selection by function keys.

```

File Name: ZOC_CONFIG_05
User ID: 26 Apr 1992 16:53:12
List of Names:
  Buffer1      Adc1      Buffer2
  Adc2        Buffer3    Adc3
  Timer

```

```

*****
Configuration for Buffer1
Model Buffer
*****
Multiprogrammer Type ... HP6954A or HP6944A
Interface Select Code .. 29
Frame ..... 0
Slot ..... 0
Initial Mode ..... FIFO
Initial Lockout ..... Off
Timeout ..... 10
Memory Type .... 69791A
No of Extenders ... 0
Ref Reg 1 ... 0
Ref Reg 2 ... 0
Buffer Direction .. In
Front End Type .. 69759A
A/D Names: 1 . Adc1
2 . None
3 . None
4 . None
5 . None
6 . None
7 . None
8 . None

```

```

*****
Configuration for Adc1
Model 69759A 500 KHz A/D
*****
Multiprogrammer type ... HP6954A or HP6944A
Interface Select Code .. 29
Frame ..... 0
Slot ..... 7
Full-scale Range ..... +-10.24 volts
Initial Internal Range ... 10
Range Source ..... Internal
Scanner ..... None
Timeout ..... 10
Data Conversion ..... Standard
Internal Trigger ..... Disabled
External Trigger ..... Enabled
Trigger Mode ..... Multiple
Trigger Polarity ..... Negative
Lockout Polarity ..... Disabled
Master Output Enable ..... Enabled
Mux Output Control ..... Disabled
External Output Enable .... Disabled
Gate Mode ..... Multiple
Return Data With ..... Sign Extension

```

[ Page 1 ]  
ZOC\_CONFIG\_05

Figure A1 ZOC-14 Configuration File

\*\*\*\*\*

Configuration for Buffer2

Model Buffer

\*\*\*\*\*

Multiprogrammer Type ... HP6954A or HP6944A  
Interface Select Code .. 29  
Frame ..... 0  
Slot ..... 2  
Initial Mode ..... FIFO  
Initial Lockout ..... Off  
Timeout ..... 10  
Memory Type .... 69781A  
No of Extenders ... 0  
Ref Reg 1 .. 0  
Ref Reg 2 ... 0  
Buffer Direction .. In  
Front End Type .. 69759A  
A/D Names: 1 . Adc2  
2 . None  
3 . None  
4 . None  
5 . None  
6 . None  
7 . None  
8 . None

\*\*\*\*\*

Configuration for Adc2

Model 69759A 500 KHz A/D

\*\*\*\*\*

Multiprogrammer Type ... HP6954A or HP6944A  
Interface Select Code .. 29  
Frame ..... 0  
Slot ..... 9  
Full-scale Range ..... +-10.24 volts  
Initial Internal Range ... 10  
Range Source ..... Internal  
Scanner ..... None  
Timeout ..... 10  
Data Conversion ..... Standard  
Internal Trigger ..... Disabled  
External Trigger ..... Enabled  
Trigger Mode ..... Multiple  
Trigger Polarity ..... Negative  
Lockout Polarity ..... Disabled  
Master Output Enable ..... Enabled  
Mux Output Control ..... Disabled  
External Output Enable .... Disabled  
Gate Mode..... Multiple  
Return Data With ..... Sign Extension

```

*****
      Configuration for Buffer3
      Model Buffer
*****
Multiprogrammer Type ... HP6954A or HP6944A
Interface Select Code .. 29
Frame ..... 0
Slot ..... 4
Initial Mode ..... FIFO
Initial Lockout ..... Off
Timeout ..... 10
Memory Type .... 69791A
No of Extenders ... 0
Ref Reg 1 .. 0
Ref Reg 2 ... 0
Buffer Direction .. In
Front End Type .. 69759A
A/D Names:  1 . Adc3
2 . None
3 . None
4 . None
5 . None
6 . None
7 . None
8 . None

```

```

*****
      Configuration for Adc3
      Model 69759A 500 KHz A/D
*****
Multiprogrammer Type ... HP6954A or HP6944A
Interface Select Code .. 29
Frame ..... 0
Slot ..... 11
Full-scale Range ..... +-10.24 volts
Initial Internal Range ... 10
Range Source ..... Internal
Scanner ..... None
Timeout ..... 10
Data Conversion ..... Standard
Internal Trigger ..... Disabled
External Trigger ..... Enabled
Trigger Mode ..... Multiple
Trigger Polarity ..... Negative
Lockout Polarity ..... Disabled
Master Output Enable ..... Enabled
Mux Output Control ..... Disabled
External Output Enable .... Disabled
Gate Mode..... Multiple
Return Data With ..... Sign Extension

```

```

*****
      Configuration for Timer
      Model Timer
*****
Multiprogrammer Type ... HP6934A or HP6944A
Interface Select Code .. 29
Timer-Pacer Frame .. 0
Timer-Pacer Slot .. 13
Counter Frame ..... 0
Counter Slot ..... 15
Counter size ... 15 Bits
Timeout ..... 10
Data Conversion ..... Standard
Run Time Limit Checking ... No
Initial Period ..... 2.E-8
Initial Count ..... 0
Digital Out Controller .. No

```

[ Page 4 ]  
ZOC\_CONFIG\_05

Figure A1 (cont) ZOC-14 Configuration File



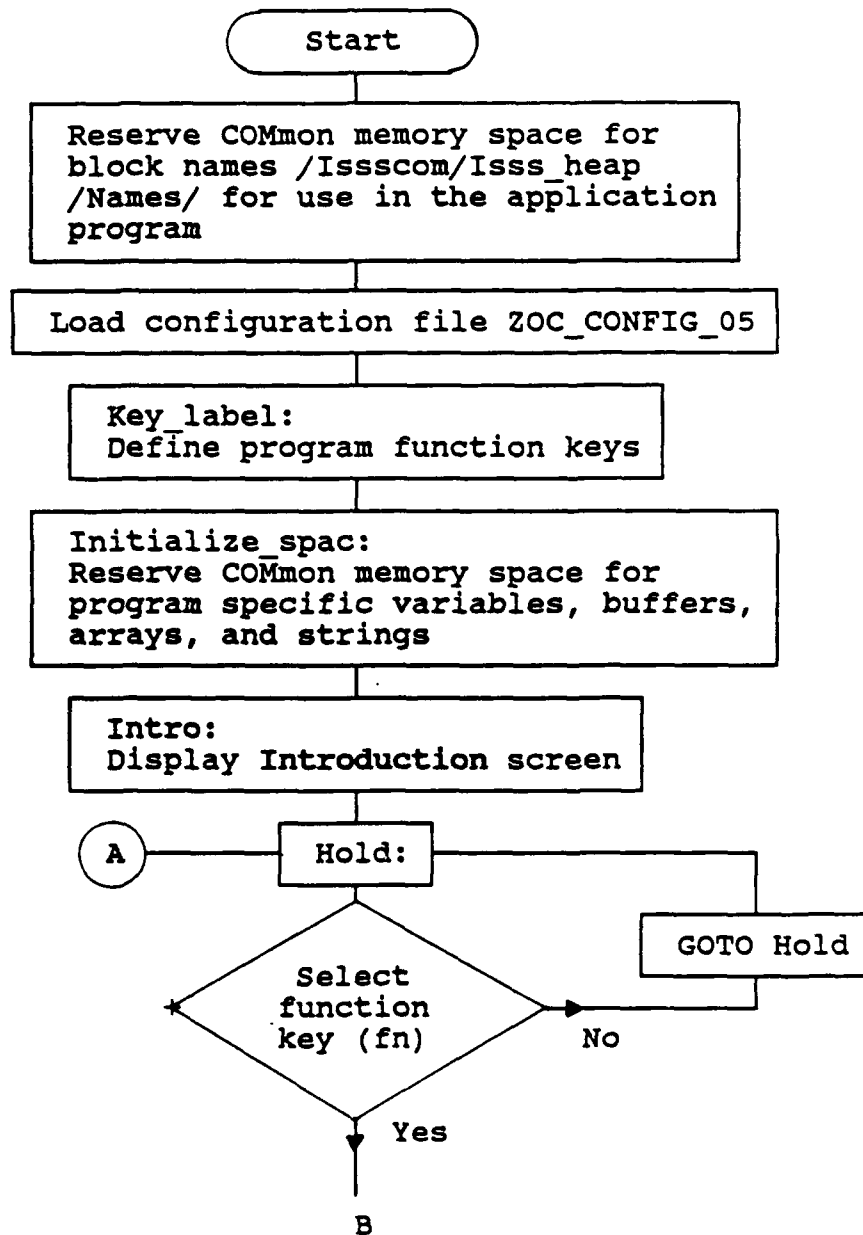


Figure A2 Program: Start-up and Initialization

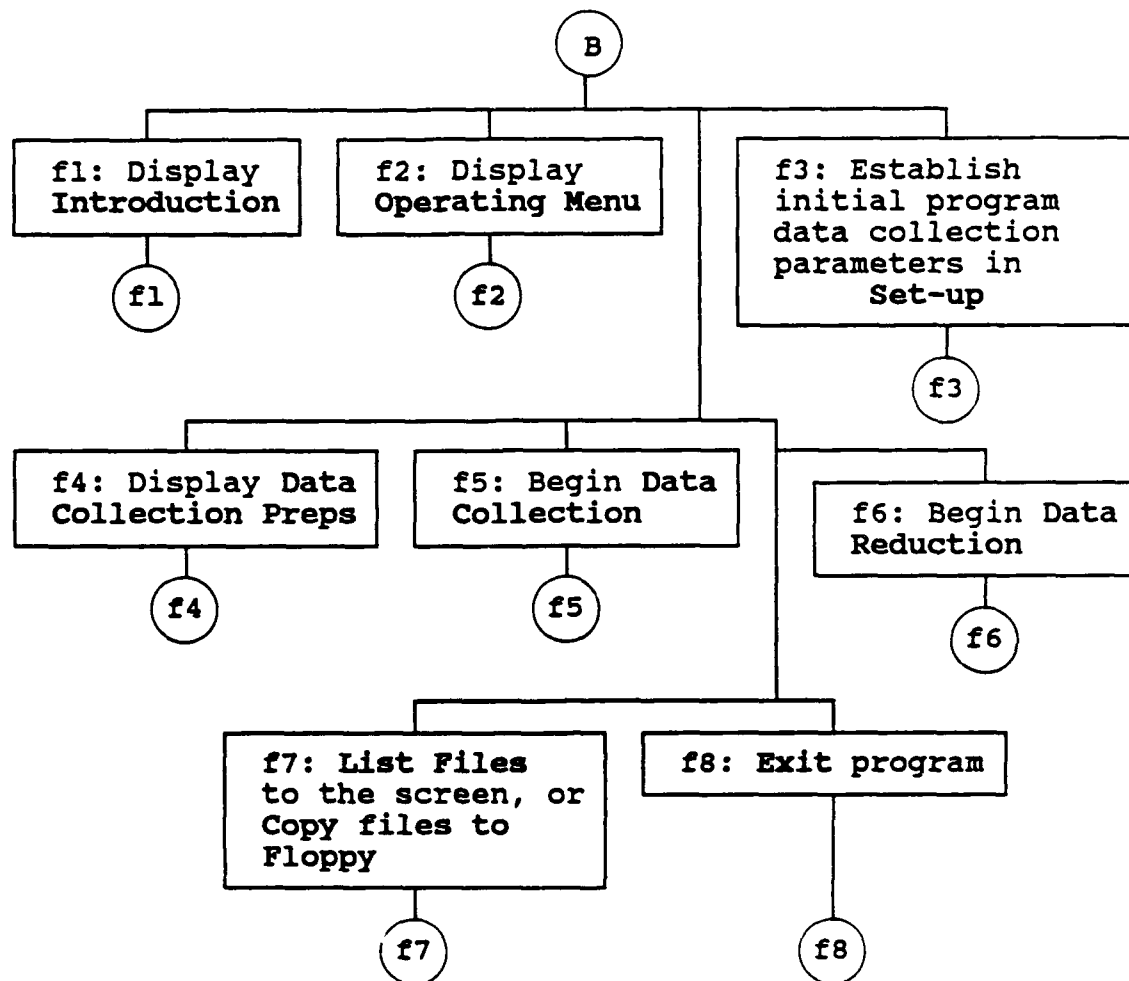


Figure A2 (cont) Program: Start-up and Initialization

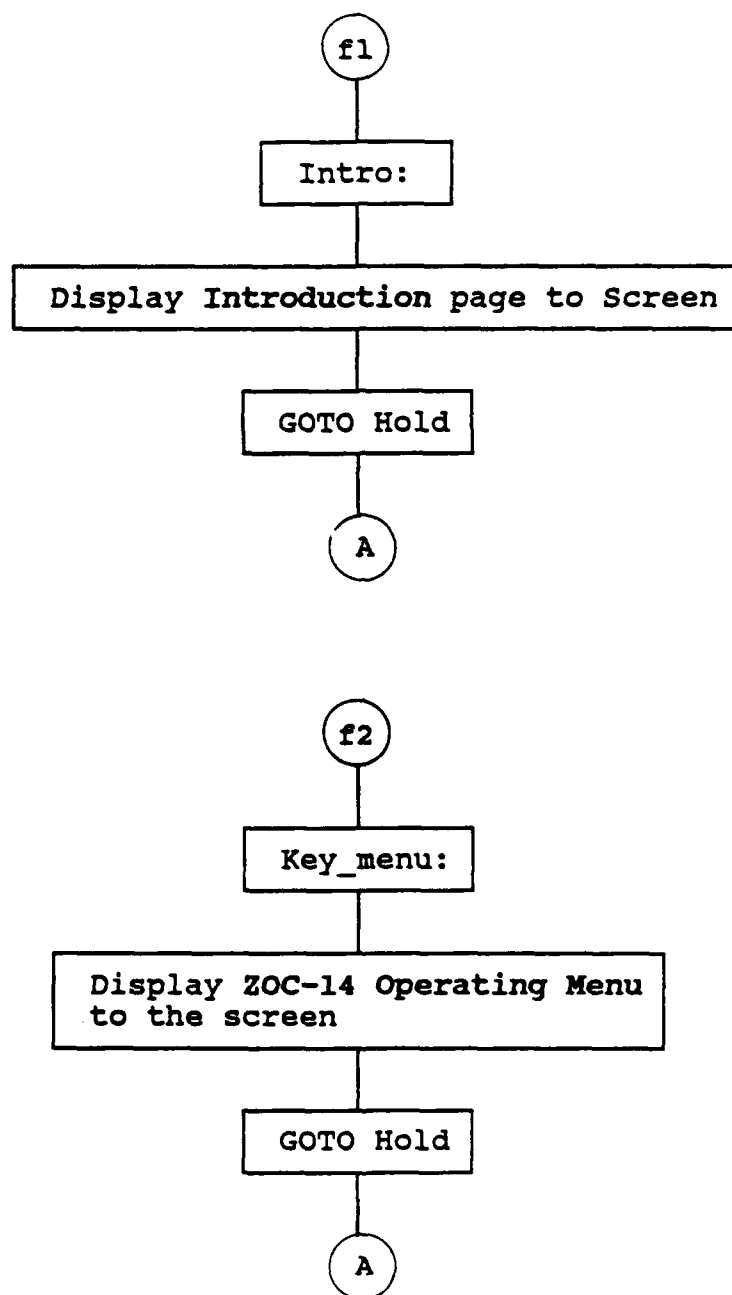


Figure A3 Program: Introduction and Operating Menu

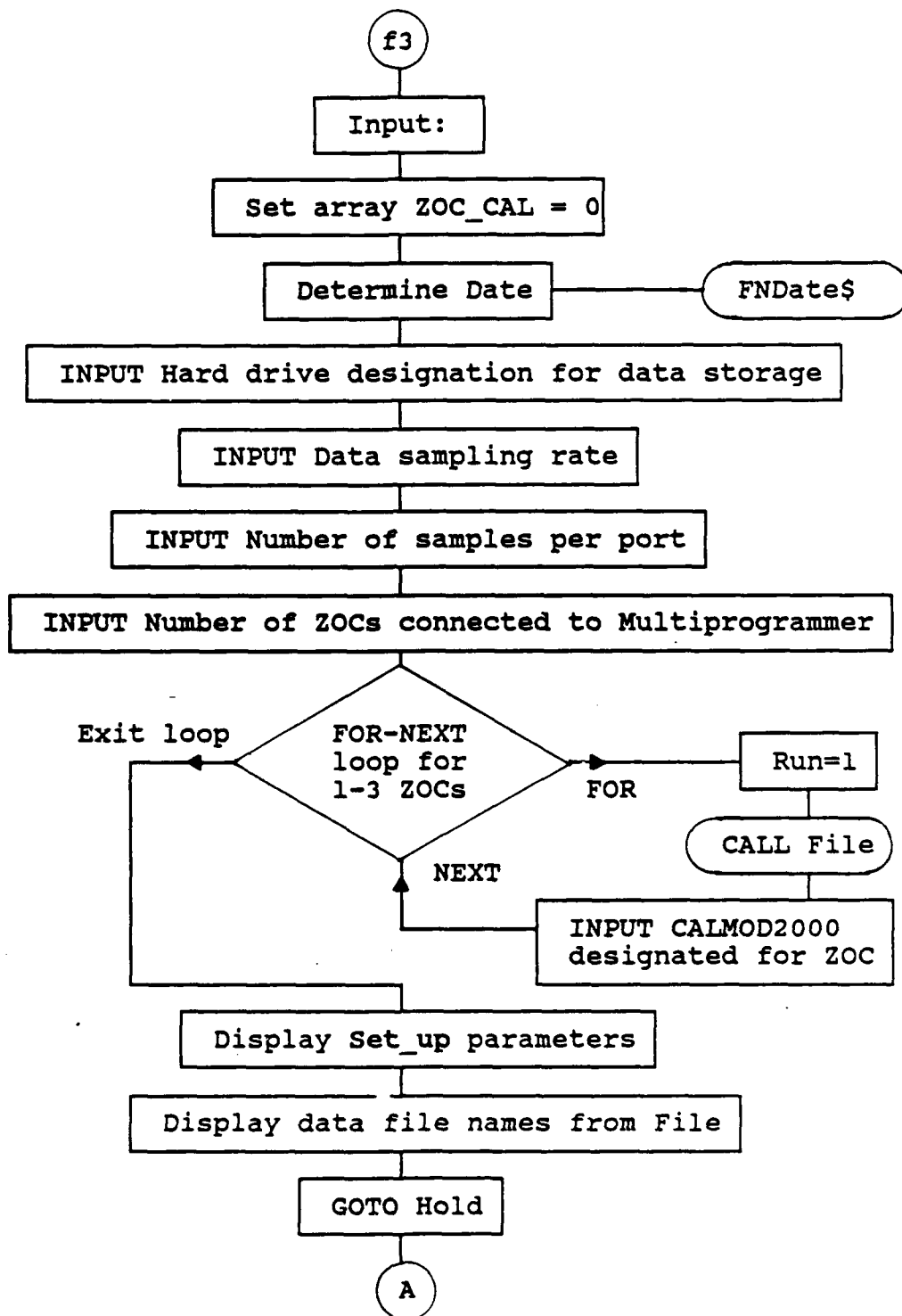


Figure A4 Program: Set-up Parameters

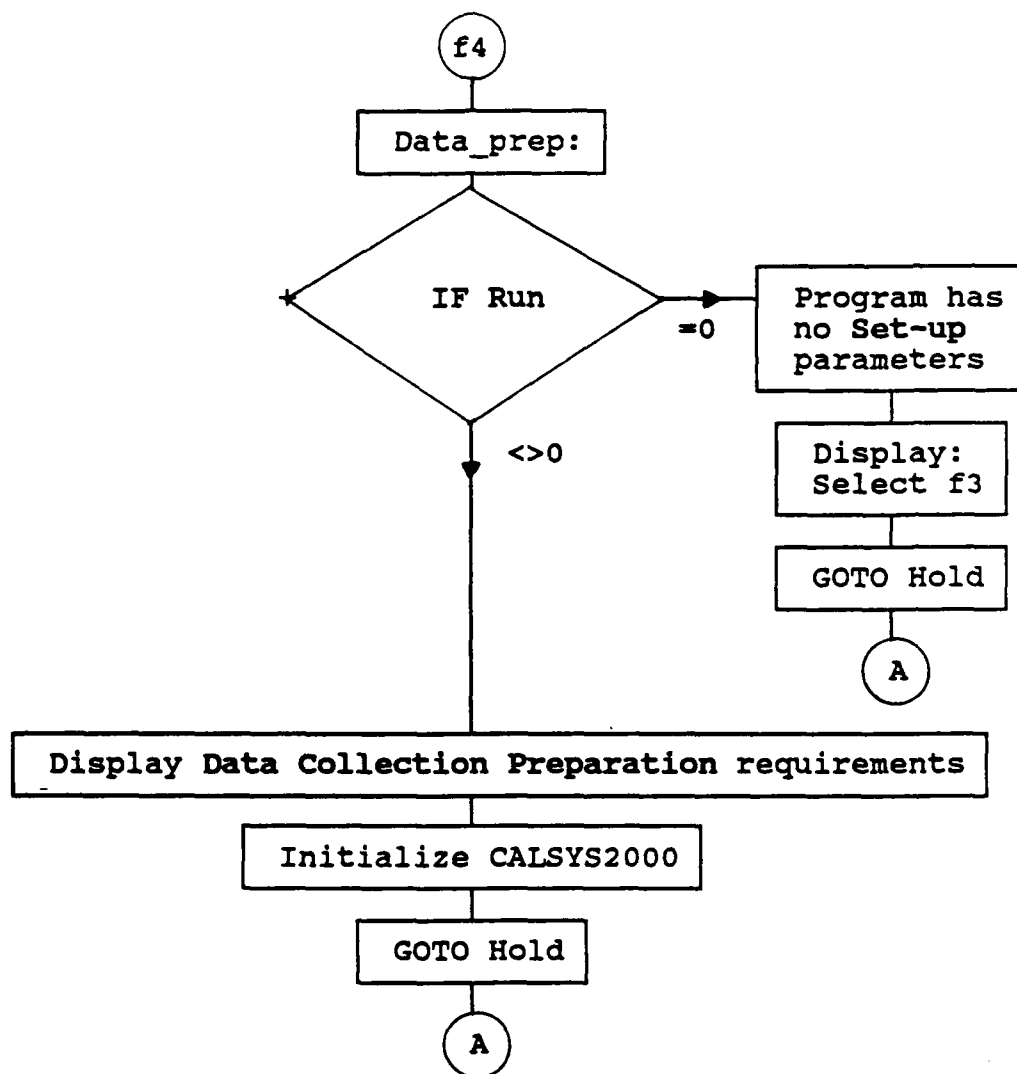


Figure A5 Program: Data Collection Preparations

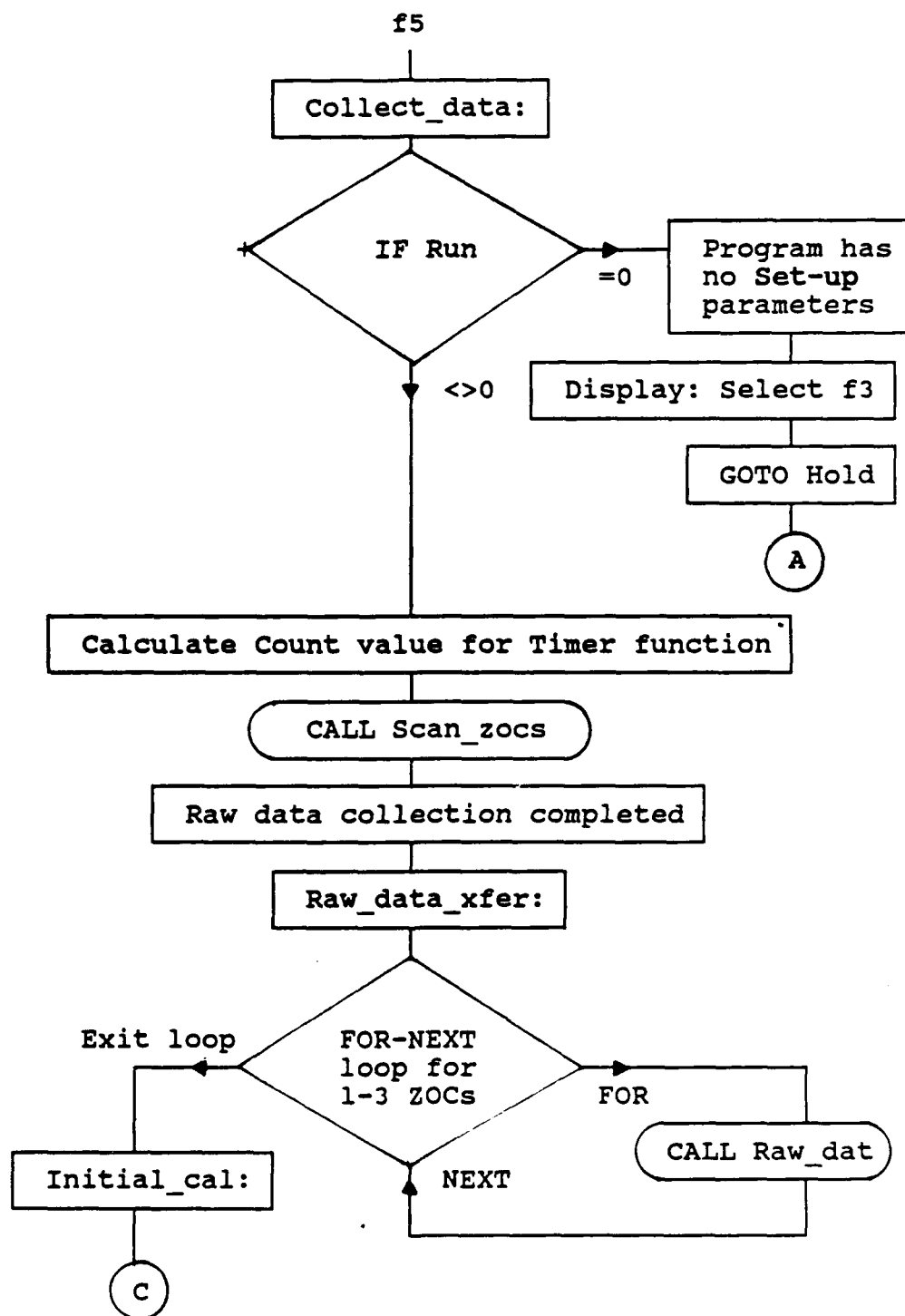


Figure A6 Program: Data Collection

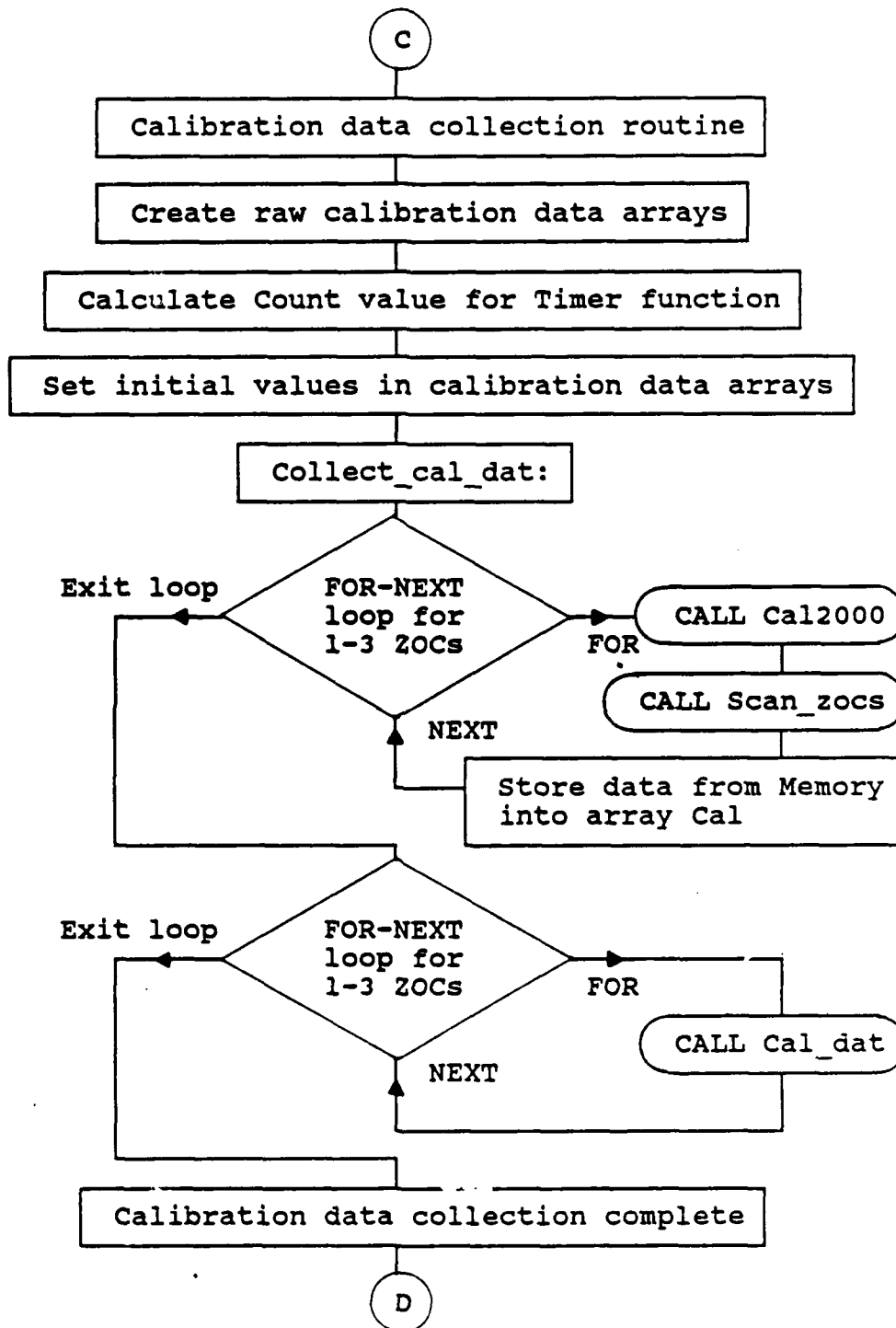


Figure A6 (cont) Program: Data Collection

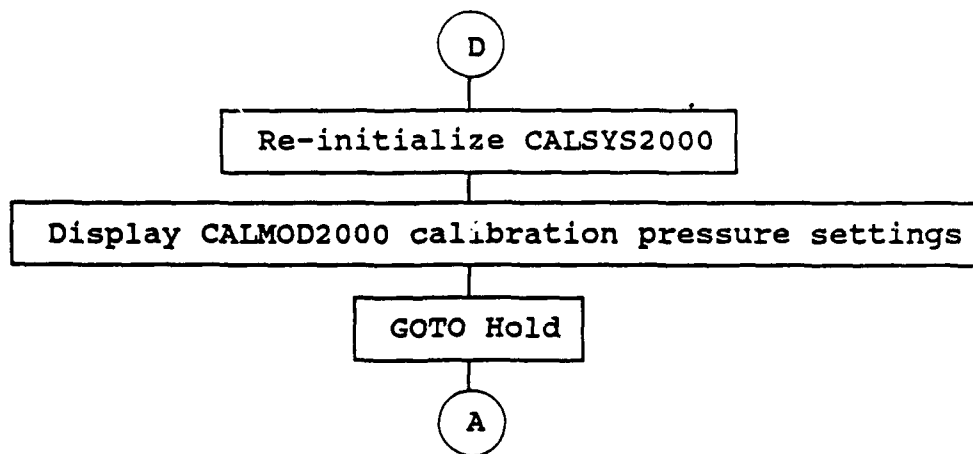


Figure A6 (cont) Program: Data Collection



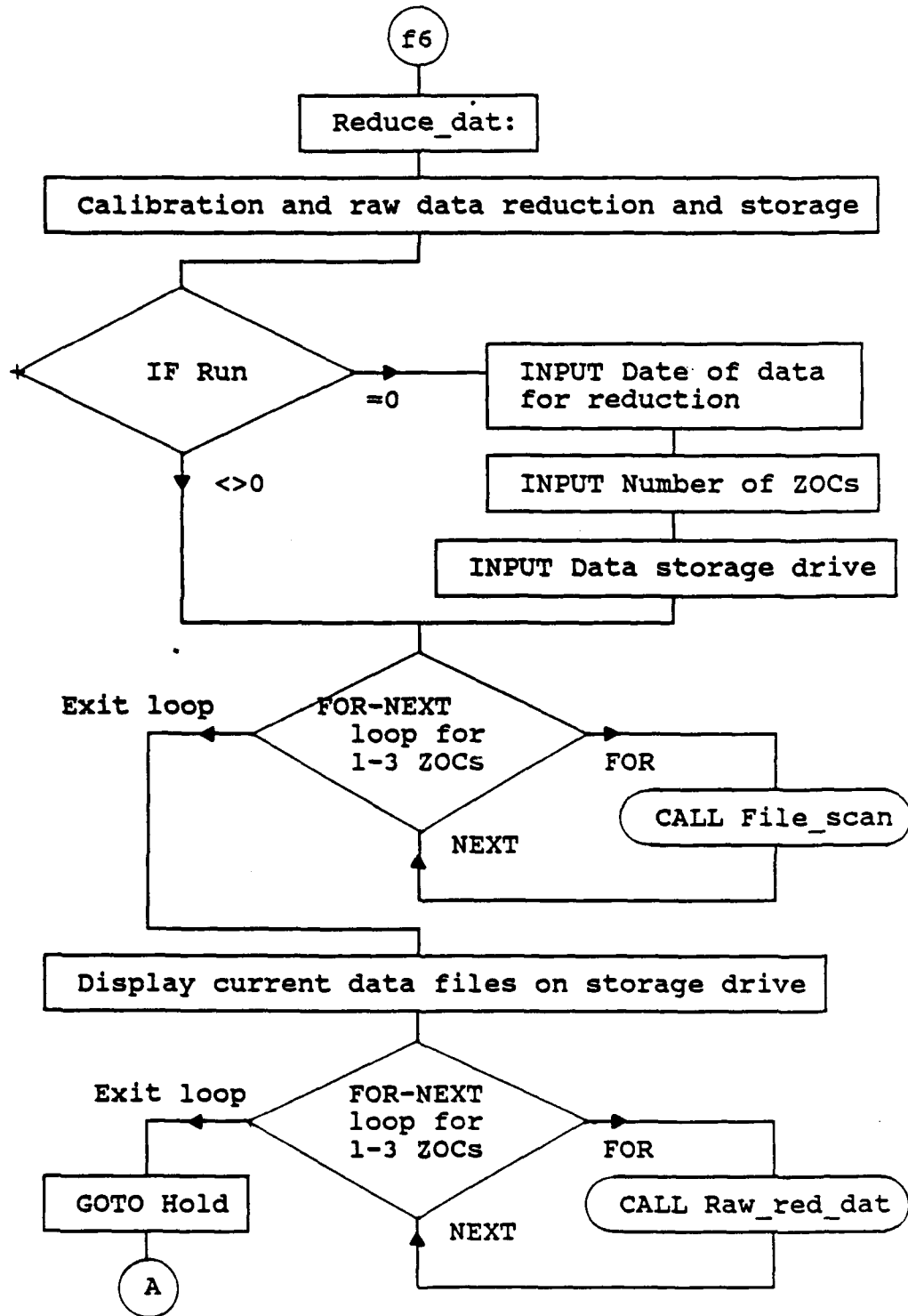


Figure A7 Program: Data Reduction and Storage

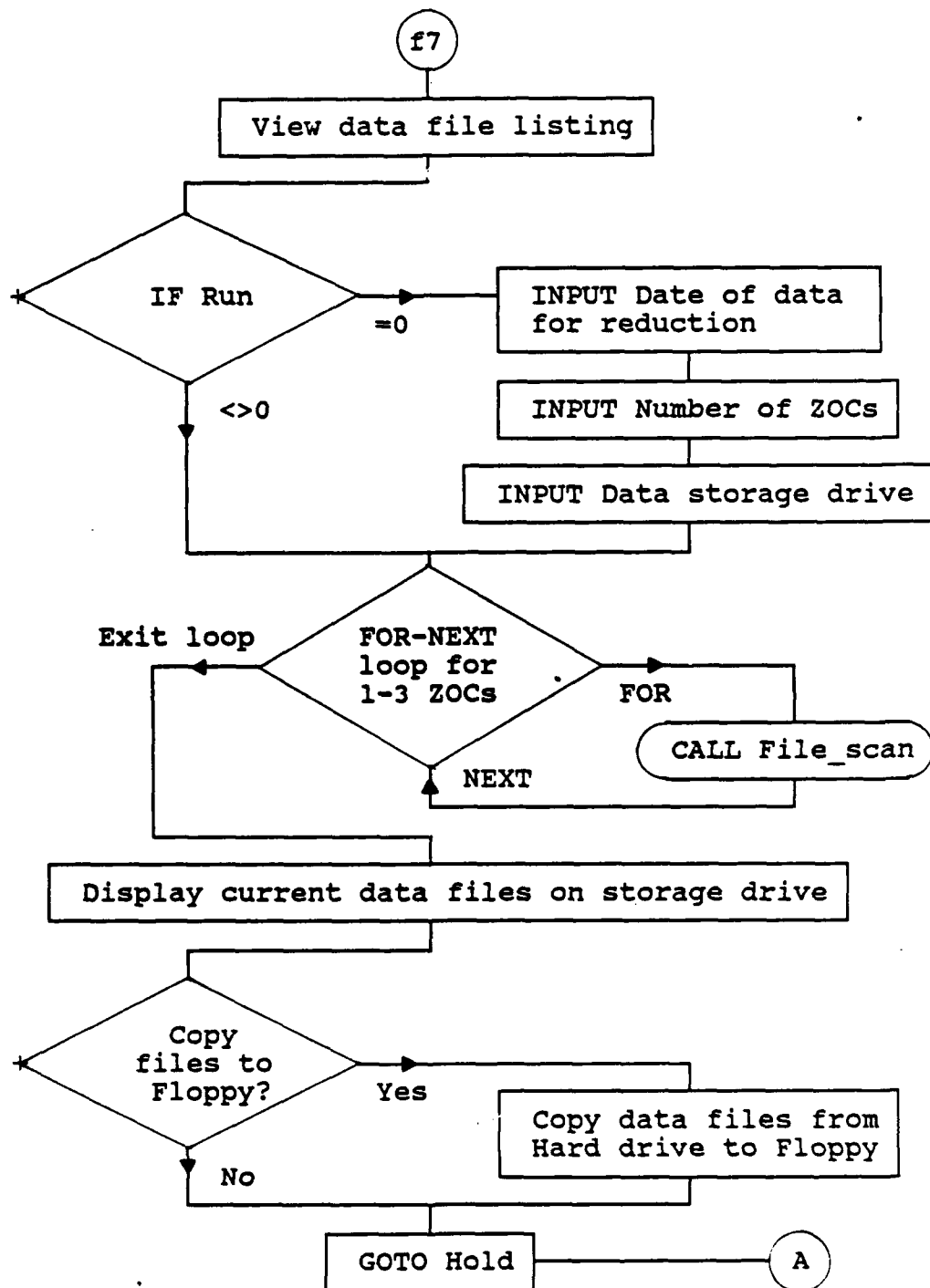


Figure A8 Program: Data File Listing and Storage

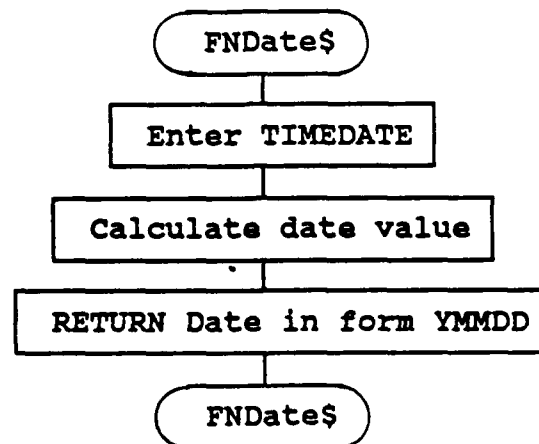
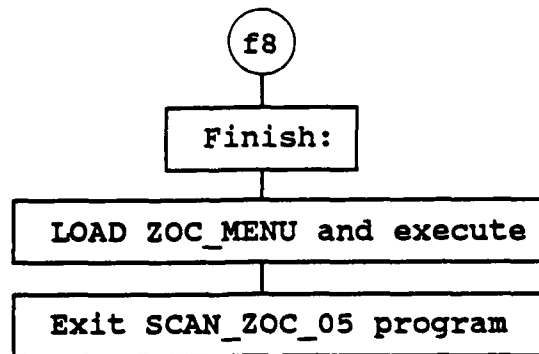


Figure A9 Program: Exit / Subprogram: FNDate\$

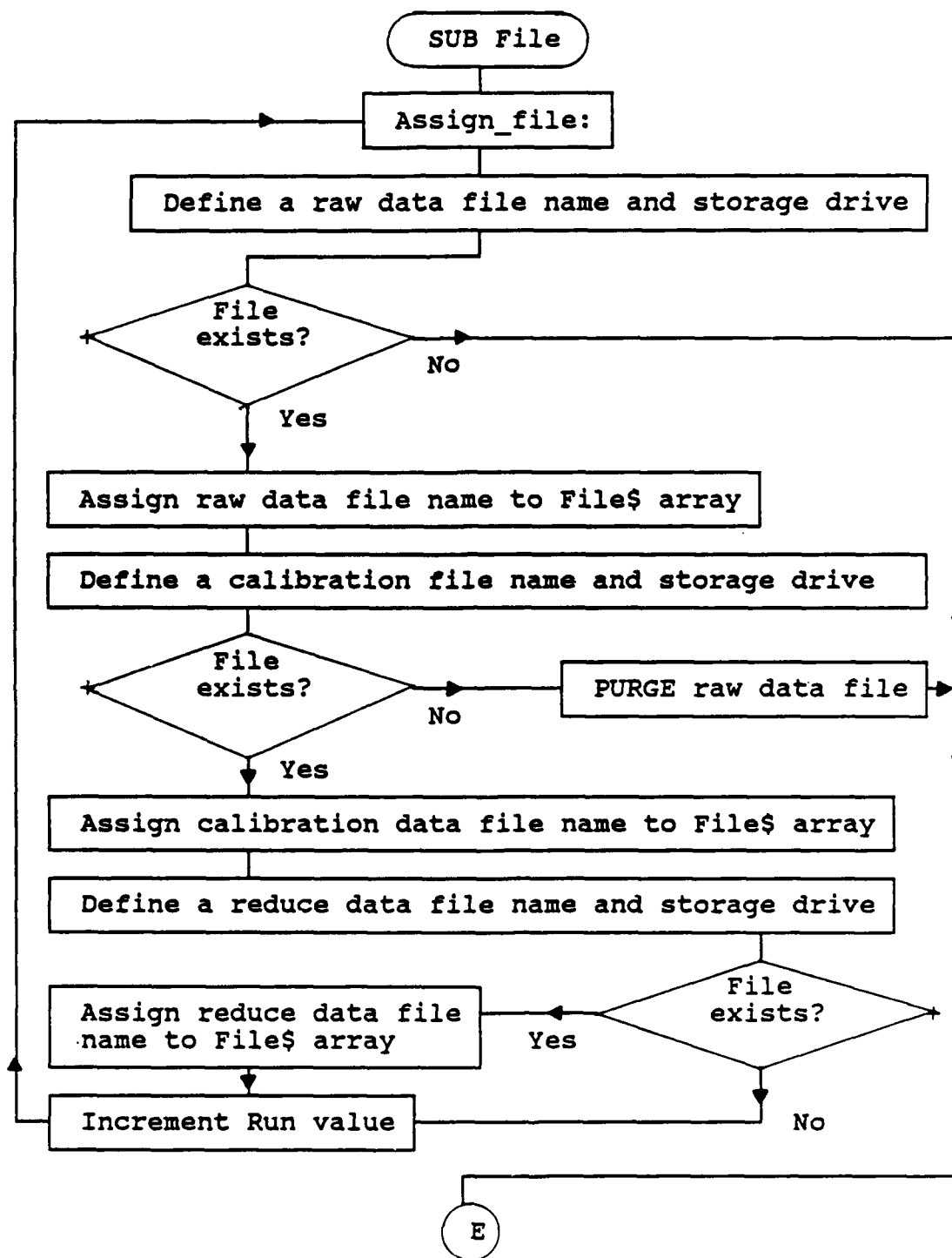


Figure A10 Subprogram: File

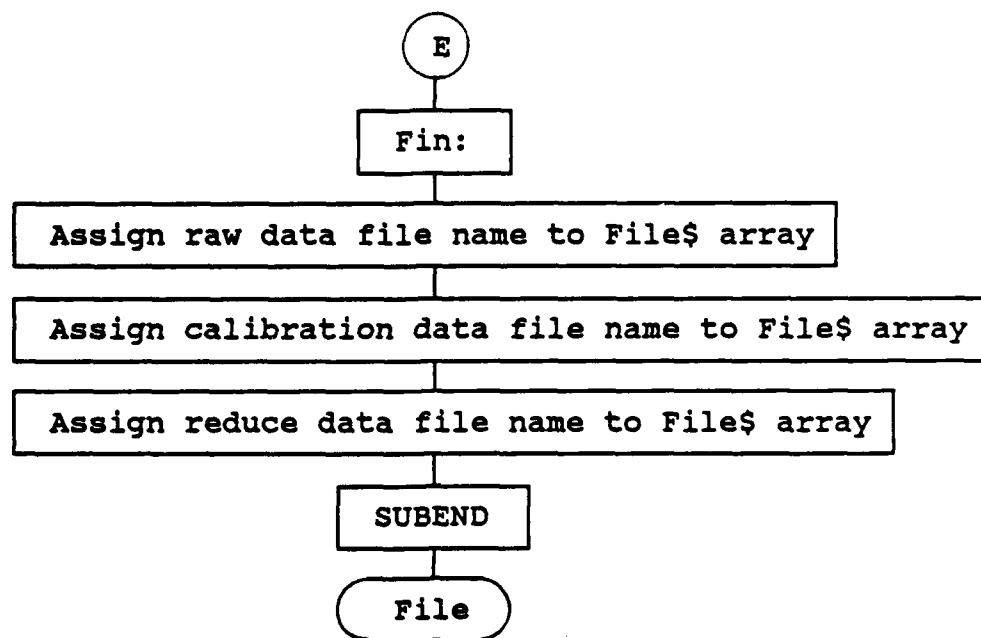


Figure A10 (cont) Subprogram: File

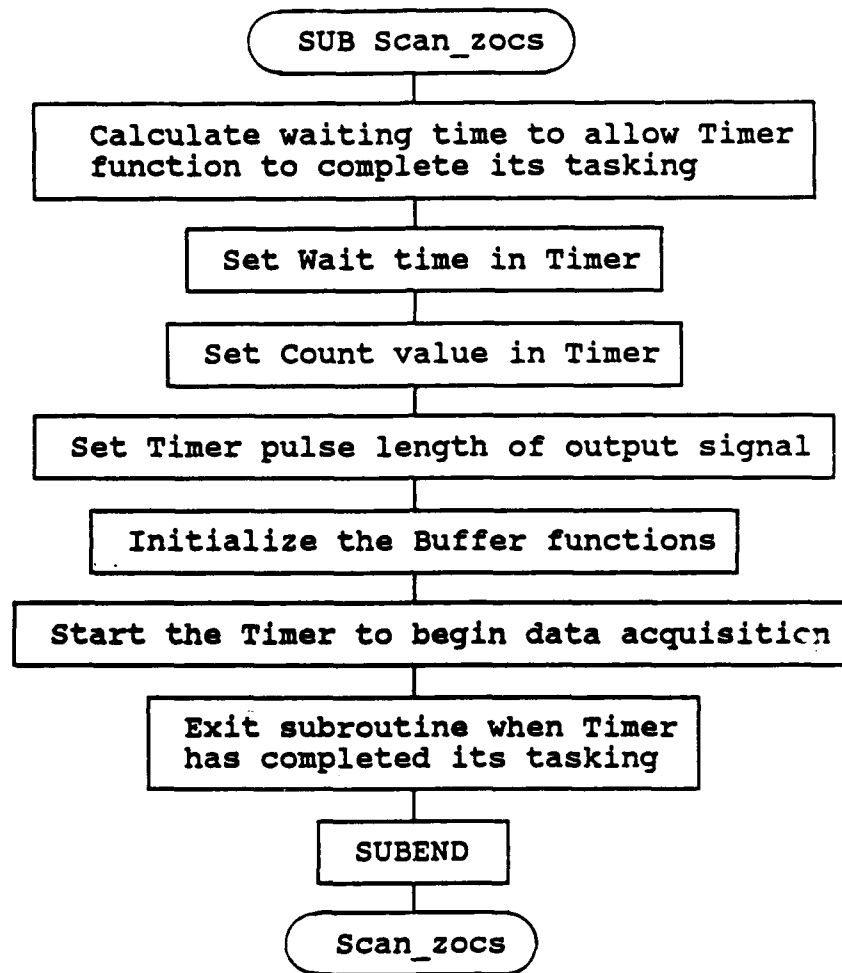


Figure A11 Subprogram: Scan\_zocs

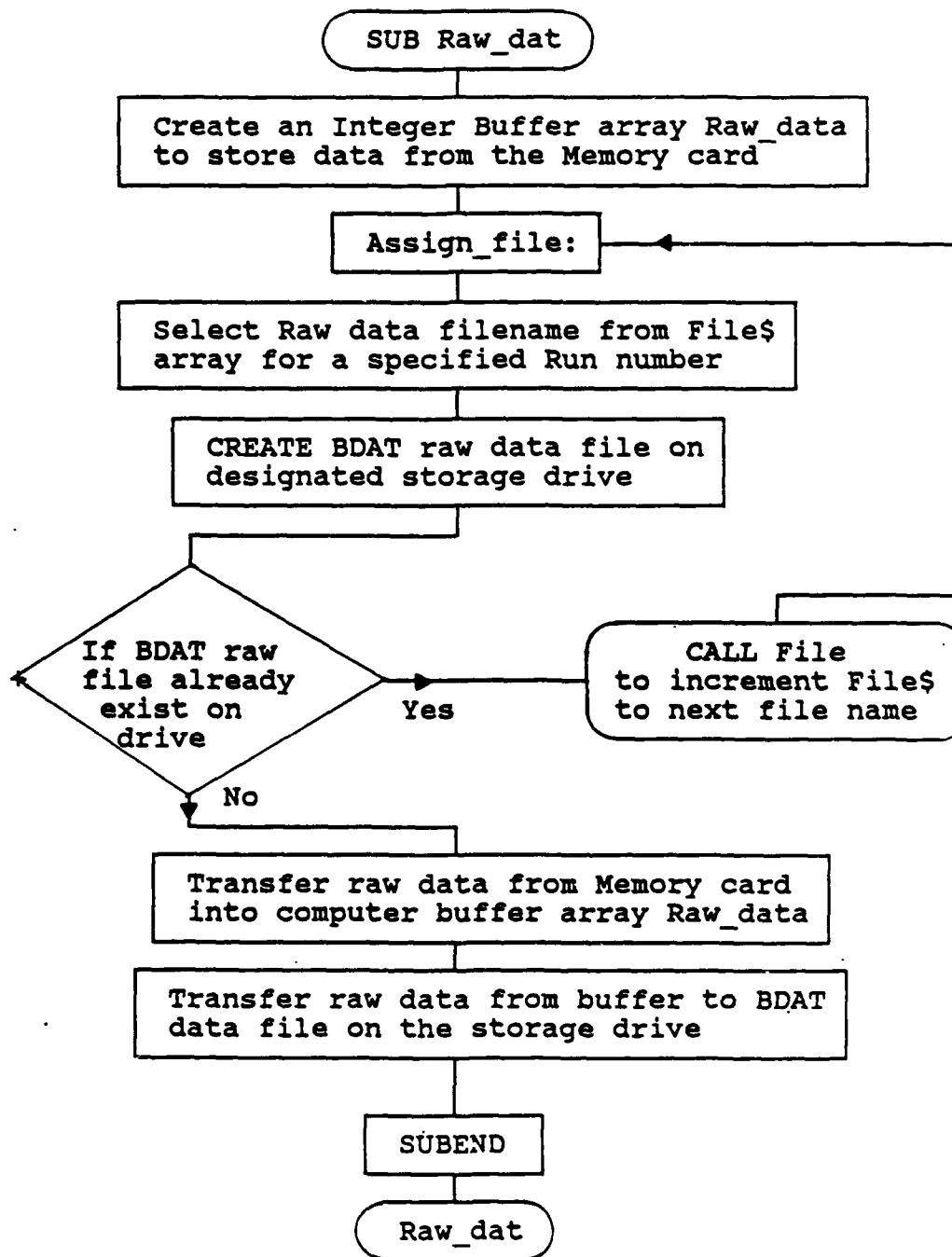


Figure A12 Subprogram: Raw\_dat

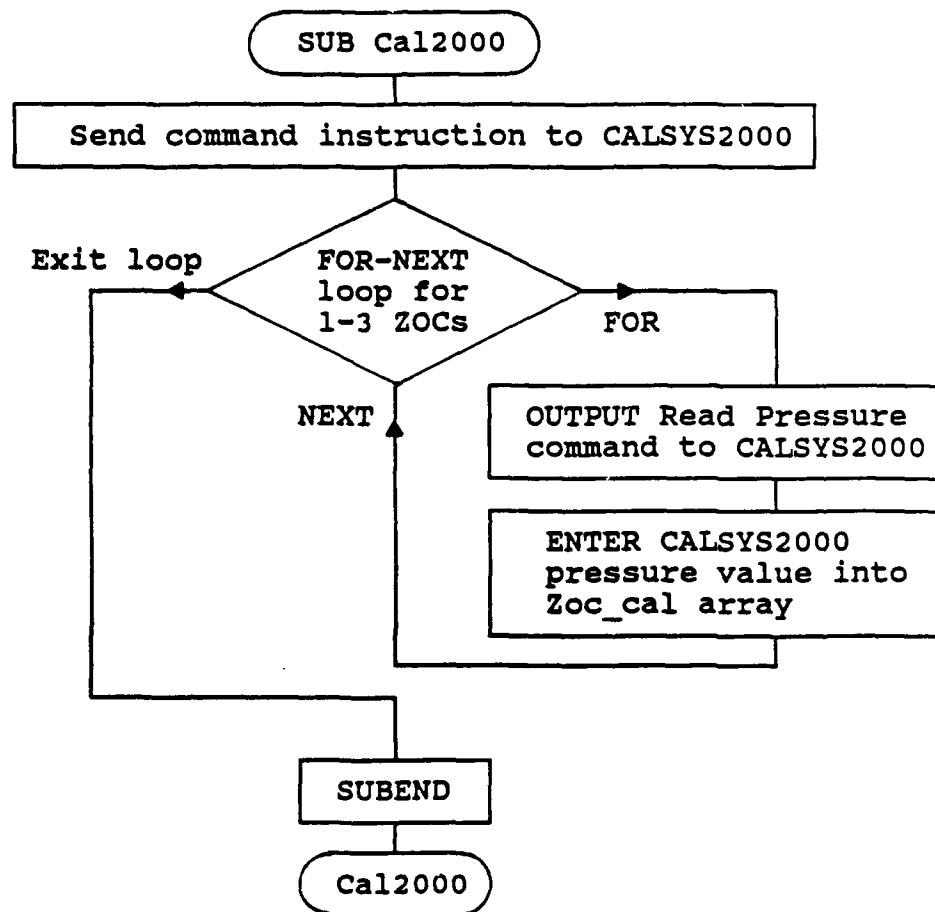


Figure A13 Subprogram: Cal2000



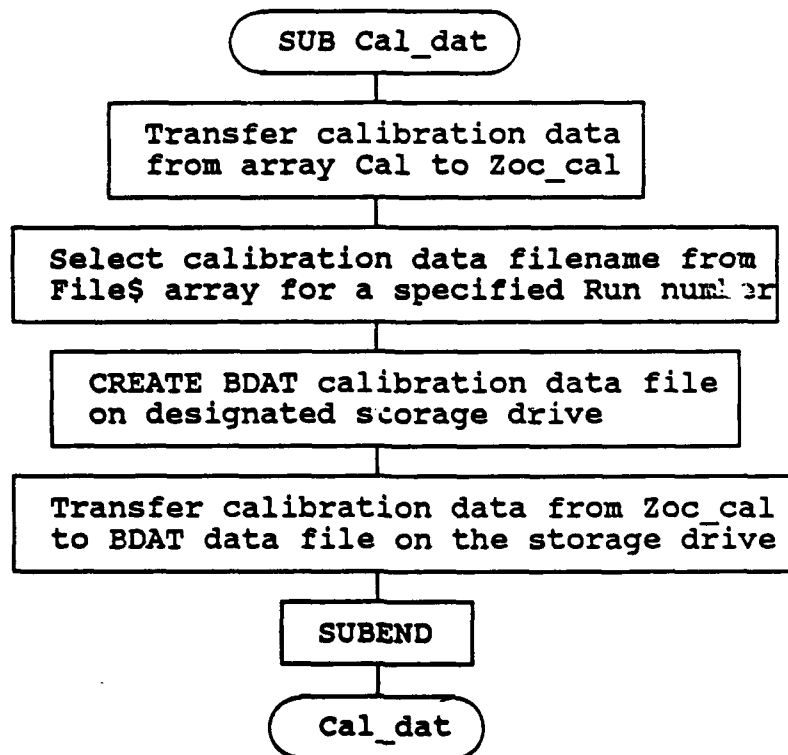


Figure A14 Subprogram: Cal\_dat

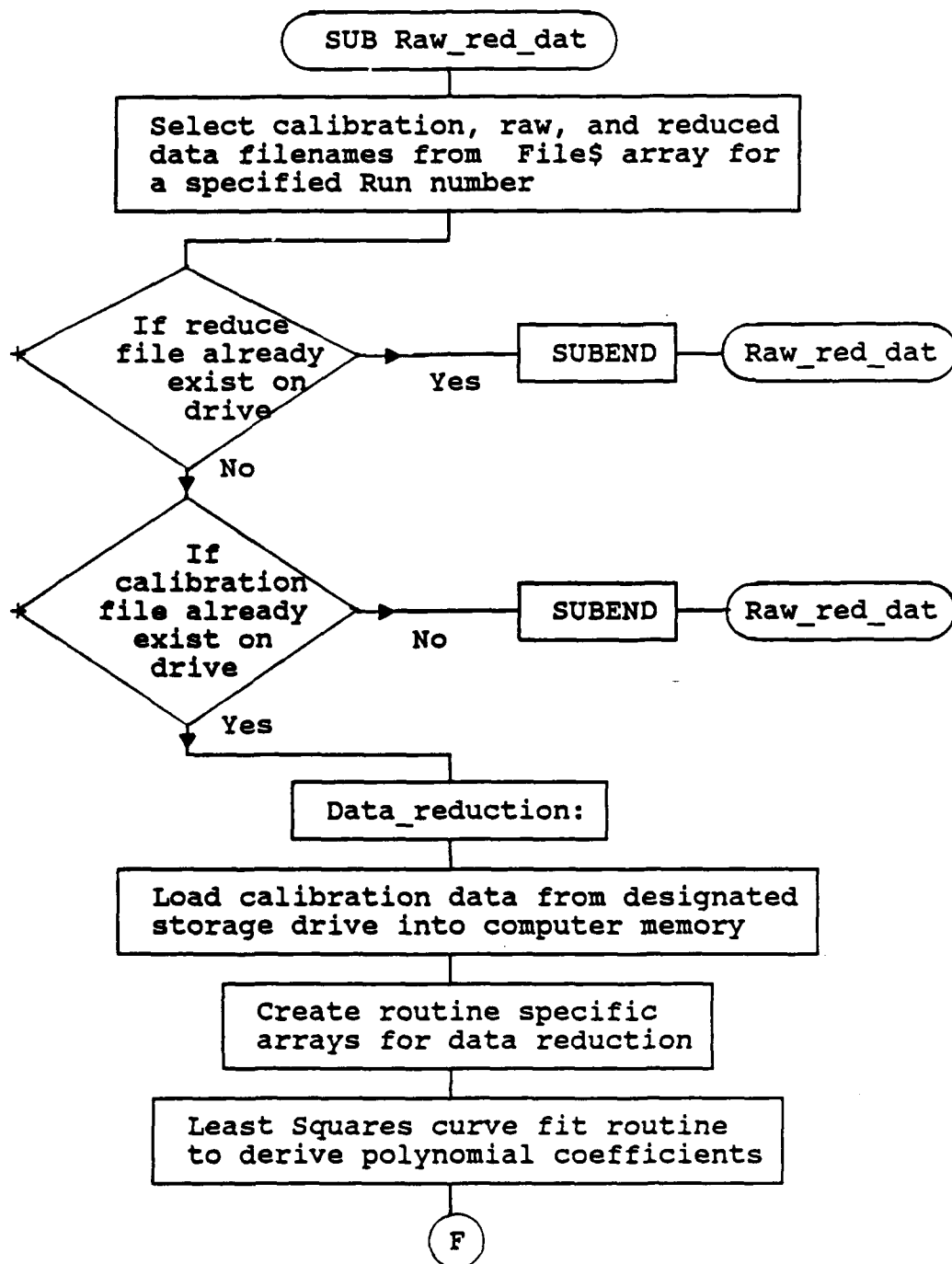


Figure A15 Subprogram: Raw\_red\_dat

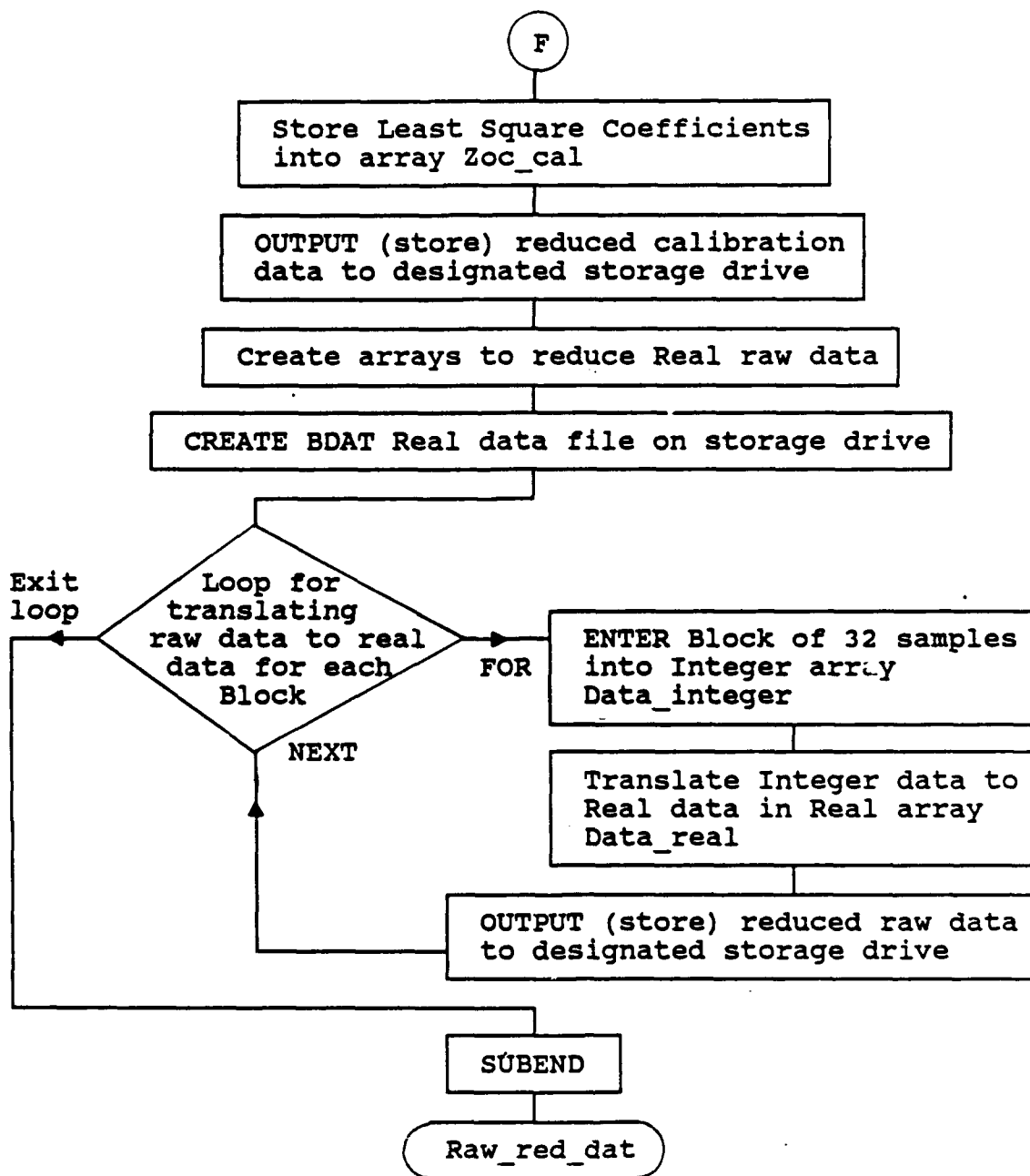


Figure A15 (cont) Subprogram: Raw\_red\_dat

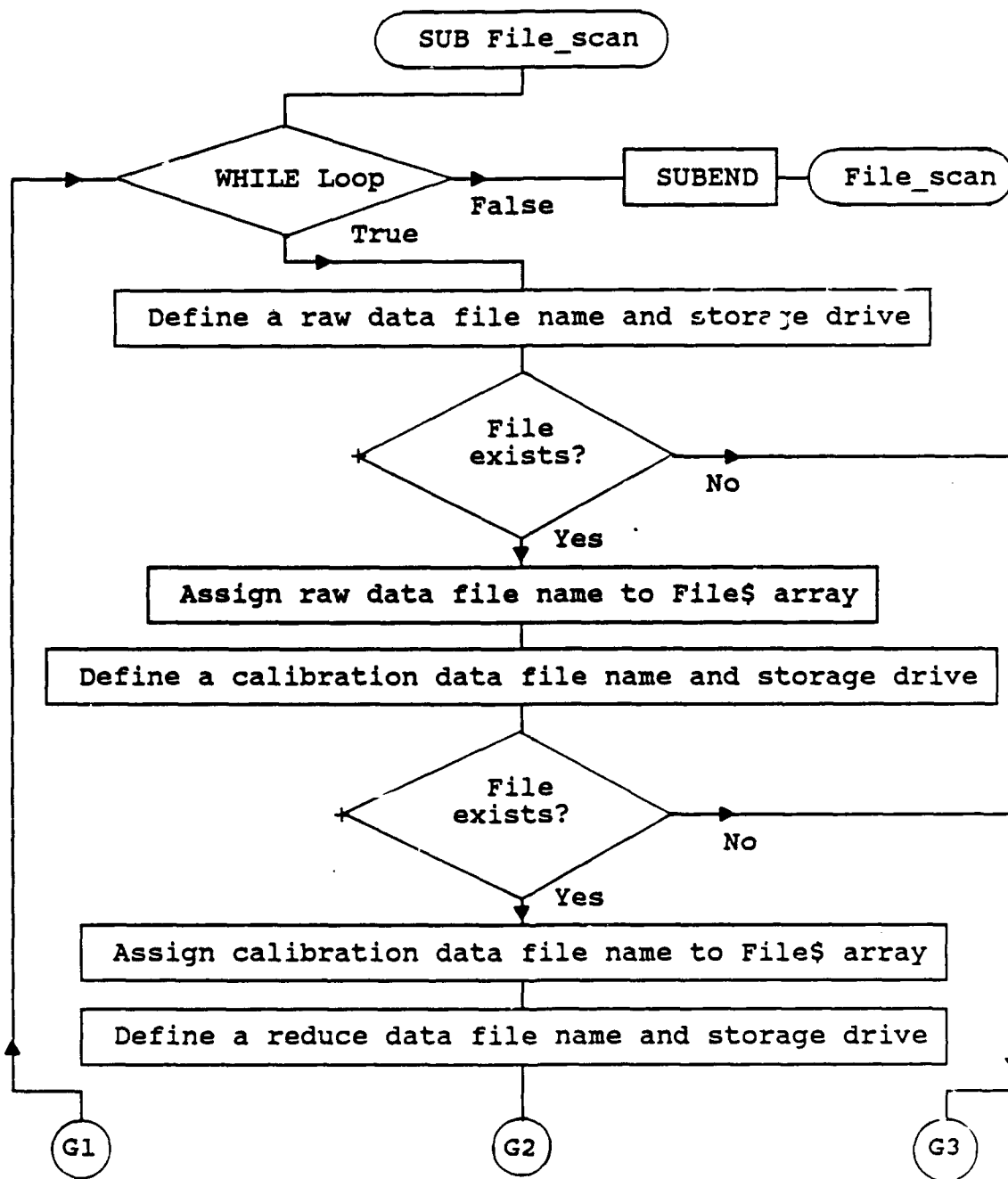


Figure A16 Subprogram: File\_scan

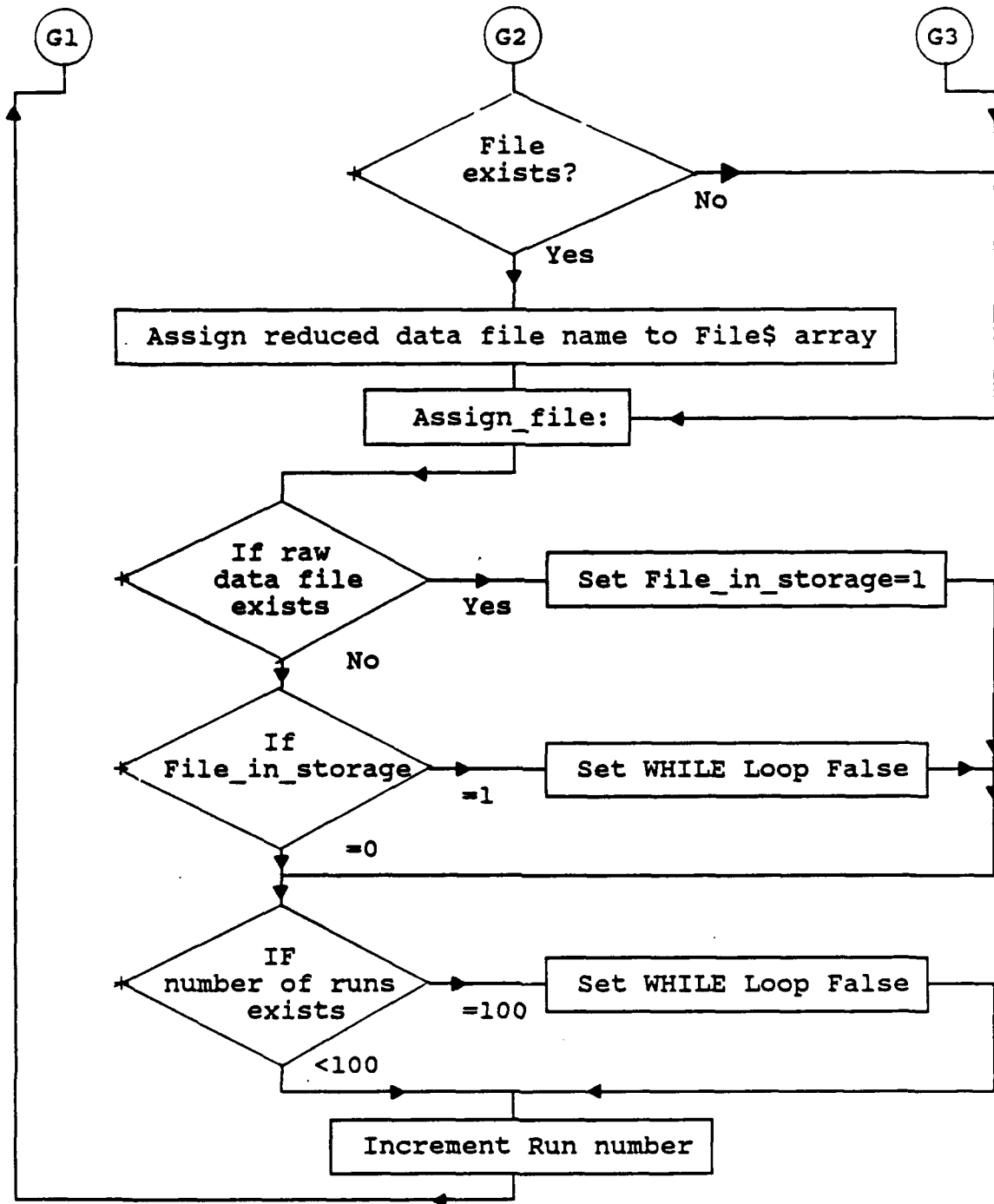


Figure A16 (cont) Subprogram: File\_scan

```

10 ! Program: SCAN_ZOC_05
20 ! Description: Application program to operate HP6944A collecting pressure
30 ! readings from 1-3 ZOC-14 32 port modules using the CALSYS
40 ! 2000 to provide calibration data, reduce raw pressure data
50 ! and store data to the hard drive.
60 ! Hardware: (1) HP6944A Multi-processors
70 ! - (3) 500 kHz A/D Cards (HP69759A)
80 ! - (3) High Speed Memory Cards (HP69791A)
90 ! - (1) Timer/Pacer Card (HP69736A)
100 ! - (1) Counter Card (HP69775A)
110 ! (1) HiScan CALSYS 2000 Calibration Module
120 ! (3) ZOC-14 32 port Electronic Pressure Scanning Modules
130 ! Notes: 1. This program utilizes up to three (3) ZOC Modules storing data
140 ! of each ZOC into a separate buffer Memory System (HP69791A).
150 ! 2. COM /Names/ line and BDAT file ZOC_CONFIG_05 must match for
160 ! this program to operate.
170 ! 3. CALSYS2000 requires a short period to stabilize before reading
180 ! the pressure valves. The Pause_for statement sets (line 470) this
190 ! wait period in seconds. Adjustment of the variable may be required
200 ! as additional ZOCs are integrated into the Data Acquisition System.
210 ! 4. CALSYS2000 currently configured for one (1) calibrator. This
220 ! program is written to operate one (1) or two (2) calibrators.
230 !
240 ! Buffer Memory: 85536 16-bit data words in HP69791A per system
250 ! Timer: Maximum 32767 counts for one HP69775A (32*1023=32736 data points)
260 ! Max speed of HP system is Period=0.000002 sec. or 500 kHz.
270 !
280 COM /Issacom/ INTEGER X(1:1106)
290 COM /Issa_heap/ Issa_heap(1000)
300 COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Buffer3,Adc3,Timer
310 Configure("Menu_off","ZOC_CONFIG_05")
320 !Configure("Ask_me","ZOC_CONFIG_05")
330 !
340 Key_label: !----- KEY LABEL ASSIGNMENT -----
350 !
360 KEY LABELS ON
370 ON KEY 1 LABEL "Intro" GOTO Intro
380 ON KEY 2 LABEL "Key Menu" GOTO Key_menu
390 ON KEY 3 LABEL "Set-up" GOTO Input
400 ON KEY 4 LABEL "Data Preps" GOTO Data_prep
410 ON KEY 5 LABEL "Collect Data" GOTO Collect_data
420 ON KEY 6 LABEL "Reduce Data" GOTO Reduce_data
430 ON KEY 7 LABEL "List Copy" GOTO View_files
440 ON KEY 8 LABEL "Exit" GOTO Finish
450 !
460 Initialize_spac: !----- ASSIGN MEMORY SPACE -----
470 Pause_for=1.5 ! Wait time for CALSYS2000 stabilization
480 ! COM assigns calibration data array for 32 Zoc ports and standard values.
490 COM /Zoc_dat/ REAL Zoc_cal1(33,10) BUFFER,Zoc_cal2(33,10) BUFFER,Zoc_cal3(33,10) BUFFER
500 COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$(6),Run
510 COM /Files/ File$(1:99,1:9){14},Data_drive$(11) !Data file & storage drive.
520 !
530 DIM Command_mode$(1:7){2}
540 Command_mode$(1)="NH"
550 Command_mode$(2)="NM"
560 Command_mode$(3)="NL"
570 Command_mode$(4)="ZO"
580 Command_mode$(5)="PL"
590 Command_mode$(6)="PM"
600 Command_mode$(7)="PH"
610 !
620 Run=0
630 Data_reduced=0
640 !
650 Intro: !----- INTRODUCTION SCREEN -----

```

Figure A17 ZOC-14 DAS Program: SCAN\_ZOC\_05

```

660 !
670 CLEAR SCREEN
680 PRINT "Introduction. Program SCAN_ZOC_05:"
690 PRINT
700 PRINT " - Scans 1-3 Zoc-14 Modules simultaneously (32 pressure sensing ports each)."
710 PRINT " - Uses Zero Operate Calibrate (ZOC) principal:"
720 PRINT " - Collects raw pressure data (Zero Operate)"
730 PRINT " - Collects calibration data (Calibrate)"
740 PRINT " - Reduces and stores data on selected hard or floppy drive."
750 PRINT " - CALSYS2000 Calibration Module used for the reference pressure standard."
760 PRINT " - Raw pressure data reduced using calibration data from CALSYS2000"
770 PRINT " and Zocs in the calibration mode."
780 PRINT
790 PRINT "Input variables: Hard and Floppy drive for data storage"
800 PRINT " Sample frequency per port (1-50,000 Hz)"
810 PRINT " Samples per Port (1-1023)"
820 PRINT " Number of Zocs and their capacity"
830 PRINT
840 ! Note: HFS Files limited to 14 characters, LIF Files limited to 10 char.
850 ! Output files have a length of 10 characters to support LIF format.
860 ! Hard drive :,700 is HFS format, :,700,0,1 is LIF format.
870 ! Floppy drive :,700,1 is LIF format.
880 PRINT "Output files: Raw data => ZW(Zoc#)(Date YMMDD)(Run#)"
890 PRINT " Calibration => ZC(Zoc#)(Date YMMDD)(Run#)"
900 PRINT " Reduced data => ZR(Zoc#)(Date YMMDD)(Run#)"
910 DISP "Select F2 key for Key Menu, F3 for system inputs, or F6 for data reduction."
920 Hold: !
930 GOTO Hold
940 !
950 Key_menu: !----- KEY MENU -----
960 !
970 CLEAR SCREEN
980 PRINT "ZOC-14 Operating Menu."
990 PRINT
1000 PRINT "Function Function Key"
1010 PRINT
1020 PRINT " Introduction F1"
1030 PRINT " Operating Menu F2"
1040 PRINT " System Set-up F3"
1050 PRINT " Data Collection Preparation F4"
1060 PRINT " Data Collection F5"
1070 PRINT " Data Reduction F6"
1080 PRINT " List Files (Copy files to Floppy) F7"
1090 PRINT
1100 PRINT " Exit F8"
1110 !
1120 GOTO Hold
1130 !
1140 Input: !----- INPUT VARIABLES -----
1150 MAT Zoc_cal1= (0)
1160 MAT Zoc_cal2= (0)
1170 MAT Zoc_cal3= (0)
1180 MAT File$= ("")
1190 Date$=FNDate$(TIMEDATE)
1200 !
1210 CLEAR SCREEN
1220 PRINT "System Set-up."
1230 PRINT
1240 INPUT "Select Hard drive for storing data (0=:,700 1=:,700,0,1)",Drv
1250 IF Drv=0 THEN
1260 Data_drive$=":,700,0,0"
1270 ELSE
1280 Data_drive$=":,700,0,1"
1290 END IF
1300 INPUT "Enter data sampling rate (1-50kHz):",Hz

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

1310 PRINT "Data acquisition rate: ";TAB(50);Hz;" Hz"
1320 INPUT "Number of samples per port (1-1023): ",Sample_number
1330 PRINT "Number of samples per port: ";TAB(50);Sample_number
1340 INPUT "Number of Zoc's connected to Multi-programmer",Zoc_number
1350 PRINT "Number of Zocs to be scanned: ";TAB(50);Zoc_number
1360 Cal_mod_id(0)=Zoc_number
1370 FOR Zoc_case=1 TO Zoc_number
1380     SELECT Zoc_case
1390     CASE 1
1400         Run=1
1410         CALL File(1)
1420         INPUT "Enter Calibration Module number set for Zoc #1 (Enter 1 or 2):",Cal_mod_id(1)
1430     CASE 2
1440         Run=1
1450         CALL File(2)
1460         INPUT "Enter Calibration Module number set for Zoc #2 (Enter 1 or 2):",Cal_mod_id(2)
1470     CASE 3
1480         Run=1
1490         CALL File(3)
1500         INPUT "Enter Calibration Module number set for Zoc #3 (Enter 1 or 2):",Cal_mod_id(3)
1510     END SELECT
1520 NEXT Zoc_case
1530 !
1540 Period=1/Hz
1550 Pulse=Period/2                !Pulse length of HP69736A trigger signal
1560 !
1570 PRINT "Total raw data acquisition time: ";TAB(50);Period*Sample_number*31;" sec."
1580 PRINT "Total calibration data acquisition time: ";TAB(50);Period*5*31+(7*Pause_for);" sec."
1590 PRINT
1600 PRINT "Data storage disc =>";Data_drive$
1610 PRINT "Data will be stored in the following files beginning with Run #";Run
1620 PRINT
1630 FOR I=1 TO Zoc_number
1640     J=(I-1)*3
1650     PRINT "Raw data file:           ";File$(Run,J+1)
1660     PRINT "Calibration data file:      ";File$(Run,J+2)
1670     PRINT "Reduced data file:             ";File$(Run,J+3)
1680     PRINT
1690 NEXT I
1700 !
1710 DISP "Select F4 key to begin data acquisition"
1720 GOTO Hold
1730 !
1740 Data_prep: !----- PREPARE FOR DATA COLLECTION -----
1750 CLEAR SCREEN
1760 PRINT "Data Collection Preparation."
1770 PRINT
1780 IF Run=0 THEN
1790     PRINT "Program not initialized for data collection."
1800     DISP "Select F3 to initialize Set-up"
1810     GOTO Hold
1820 END IF
1830 PRINT "Check list:"
1840 PRINT " - HiScan CALSYS2000 on-line"
1850 PRINT " - CALMOD supply line valve is OPEN (on back of CALSYS2000)"
1860 PRINT " - CALSYS2000 (Nitrogen) pressure source at 90 psi"
1870 !
1880 !
1890 CONTROL 9,5,3                ! Set DTR & RTS to Active for CALSYS2000
1900 OUTPUT 9;VAL$(1);"IC";CHR$(13);END! Initialize Calibrator module #1
1910 OUTPUT 9;VAL$(2);"IC";CHR$(13);END! Initialize Calibrator module #2
1920 WAIT Pause_for                ! Allow CALSYS2000 to set Zocs
1930 !
1940 DISP "Select F5 to start data acquisition"
1950 GOTO Hold

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05



```

1960 !
1970 Collect_data: !----- COLLECT DATA -----
1980 IF Run=0 THEN
1990 PRINT "Program not initialized for data collection."
2000 DISP "Select F3 to initialize Set-up"
2010 GOTO Hold
2020 END IF
2030 CLEAR SCREEN
2040 PRINT
2050 PRINT "Collecting raw pressure data."
2060 Count=Sample_number*32 ! Set Count as function of sample number
2070 ! and number of port readings (32) on
2080 ! Zoc for raw data collection.
2090 CALL Scan_zocs(Count,Pulse) ! Collect raw data into Memory System
2100 PRINT
2110 PRINT "Raw data collection complete."
2120 BEEP
2130 !
2140 Raw_data_xfer: !----- TRANSFER RAW DATA FM MEMORY SYSTEM TO HARD DISC -----
2150 PRINT
2160 !
2170 FOR Zoc_case=1 TO Zoc_number ! Collect raw data, reduce data and
2180 SELECT Zoc_case ! and store reduce data on hard drive
2190 CASE 1
2200 CALL Raw_dat(Buffer1,1)
2210 CASE 2
2220 IF Run>1 THEN
2230 Run=Run-1
2240 END IF
2250 CALL Raw_dat(Buffer2,2)
2260 CASE 3
2270 IF Run>1 THEN
2280 Run=Run-1
2290 END IF
2300 CALL Raw_dat(Buffer3,3)
2310 END SELECT
2320 NEXT Zoc_case
2330 !
2340 Initial_cal: !----- CALIBRATION SET-UP -----
2350 ! Calibration data array for each Zoc: Zoc_cal_(33,10)
2360 ! Format:
2370 ! For ports i=1 to 33
2380 ! Row 0, column 0: Period
2390 ! Row 0, column 1: Sample number
2400 ! Row 0, column 2: Zoc #
2410 ! Row 0, column 3: Calibrator module ID (1=50 psi 2=15 psi)
2420 ! Row 0: NH NM NL ZO PL PM PH (pressure Hg.)
2430 ! Row 1: A0 A1 A2 A3 NH NM NL ZO PL PM PH (LS coef, press volts)
2440 ! LS coef are Least Squares curve fit coef for third order polynomial.
2450 !
2460 PRINT
2470 PRINT "Collecting calibration data."
2480 REAL Cal1(1120),Cal2(1120),Cal3(1120)! Calibration data array
2490 Count=32*5 ! Set count to collect calibration data
2500 !
2510 MAT Zoc_cal1= (0)
2520 MAT Zoc_cal2= (0)
2530 MAT Zoc_cal3= (0)
2540 Zoc_cal1(0,0)=Period
2550 Zoc_cal1(0,1)=Sample_number
2560 Zoc_cal1(0,2)=1
2570 Zoc_cal1(0,3)=Cal_mod_id(1)
2580 Zoc_cal2(0,0)=Period
2590 Zoc_cal2(0,1)=Sample_number
2600 Zoc_cal2(0,2)=2

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

2610 Zoc_cal2(0,3)=Cal_mod_id(2)
2620 Zoc_cal3(0,0)=Period
2630 Zoc_cal3(0,1)=Sample_number
2640 Zoc_cal3(0,2)=3
2650 Zoc_cal3(0,3)=Cal_mod_id(3)
2660 !
2670 Collect_cal_dat: !----- COLLECT RAW CALIBRATION DATA -----
2680 !
2690 ! Collect raw calibration data for each CALSYS2000 setting
2700 FOR Index=1 TO 7
2710     CALL Cal2000(Command_mode$(Index),Index)
2720     CALL Scan_zocs(Count,Pulse)
2730     FOR Zoc_case=1 TO Zoc_number
2740         SELECT Zoc_case
2750             CASE 1
2760                 Input_rblock(Buffer1,Cal1(*),160,(Index-1)*160+1)
2770             CASE 2
2780                 Input_rblock(Buffer2,Cal2(*),160,(Index-1)*160+1)
2790             CASE 3
2800                 Input_rblock(Buffer3,Cal3(*),160,(Index-1)*160+1)
2810         END SELECT
2820     NEXT Zoc_case
2830 NEXT Index
2840 !
2850 ! Store collected calibration data
2860 FOR Zoc_case=1 TO Zoc_number
2870     SELECT Zoc_case
2880         CASE 1
2890             CALL Cal_dat(Cal1(*),Zoc_cal1(*))
2900         CASE 2
2910             CALL Cal_dat(Cal2(*),Zoc_cal2(*))
2920         CASE 3
2930             CALL Cal_dat(Cal3(*),Zoc_cal3(*))
2940     END SELECT
2950 NEXT Zoc_case
2960 !
2970 PRINT
2980 PRINT "Calibration data collection complete."
2990 BEEP
3000 WAIT .25
3010 BEEP
3020 OUTPUT 9;VAL$(1);"IC";CHRS(13);END! Initialize Calibrator module #1
3030 OUTPUT 9;VAL$(2);"IC";CHRS(13);END! Initialize Calibrator module #2
3040 PRINT
3050 PRINT "*** Secure Calibrator pressure valve to conserve Nitrogen ***"
3060 PRINT
3070 PRINT "CALSYS2000 Calibration modes and pressures (in Hg):"
3080 Fmt1:IMAGE /,5X,K,10X,K,10X,K,10X,K
3090 PRINT USING Fmt1;"Mode","Zoc #1","Zoc #2","Zoc #3"
3100 Fmt2:IMAGE 5X,K,10X,3D.4D,8X,3D.4D,8X,3D.4D
3110 FOR I=4 TO 10
3120     PRINT USING Fmt2;Command_mode$(I-3),Zoc_cal1(0,I),Zoc_cal2(0,I),Zoc_cal3(0,I)
3130 NEXT I
3140 DISP "Select F4 for another data run, or F8 to reduce data"
3150 GOTO Hold
3160 !
3170 Reduce_data: !----- REDUCE DATA AND STORE ON HARD DRIVE -----
3180 ! Routine loads raw and calibration data from storage drive, reduces the
3190 ! data, and stores the data to the storage drive.
3200 !
3210 CLEAR SCREEN
3220 PRINT "Calibration and Raw data reduction and storage."
3230 PRINT
3240 IF Run=0 THEN
3250     INPUT "Enter the date of data for for reduction (YYMMDD):",Date$

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

3260 INPUT "Number of Zoc's connected to Multi-programmer",Zoc_number
3270 INPUT "Select data storage drive (0=,700 1=,700,0,1 2=,700,1)",Drv_case
3280 SELECT Drv_case
3290 CASE 0
3300 Data_drive$=":,700,0,0"
3310 CASE 1
3320 Data_drive$=":,700,0,1"
3330 CASE 2
3340 Data_drive$=":,700,1"
3350 END SELECT
3360 END IF
3370 !
3380 MAT File$= ("")
3390 FOR Zoc_case=1 TO Zoc_number !Assign files from storage to File$(*)
3400 SELECT Zoc_case
3410 CASE 1
3420 CALL File_scan(1)
3430 CASE 2
3440 CALL File_scan(2)
3450 CASE 3
3460 CALL File_scan(3)
3470 END SELECT
3480 NEXT Zoc_case
3490 !
3500 PRINT "Current files on storage disc ";Data_drive$;" for date ";Date$
3510 PRINT
3520 FOR Rn=1 TO Run
3530 FOR Zn=1 TO Zoc_number
3540 FOR I=1 TO 3
3550 PRINT USING "3X,K,0";File$(Rn,(Zn-1)*3+I)
3560 NEXT I
3570 PRINT USING "+,L"
3580 NEXT Zn
3590 NEXT Rn
3600 PRINT
3610 !
3620 FOR Run_red=1 TO Run ! Reduce data routine.
3630 FOR Zoc_case=1 TO Zoc_number
3640 SELECT Zoc_case
3650 CASE 1
3660 CALL Raw_red_dat(1,Run_red)
3670 CASE 2
3680 CALL Raw_red_dat(2,Run_red)
3690 CASE 3
3700 CALL Raw_red_dat(3,Run_red)
3710 END SELECT
3720 NEXT Zoc_case
3730 NEXT Run_red
3740 Run=0
3750 Data_reduced=1
3760 BEEP
3770 DISP "Select F3 reinitialize set-up for data collection, or F8 to Exit"
3780 GOTO Hold
3790 !
3800 View_files: !----- VIEW FILES ON STORAGE DRIVE -----
3810 ! Routine loads files from storage drive and displays file names.
3820 !
3830 CLEAR SCREEN
3840 PRINT "List Raw, Calibration and Reduced data files."
3850 PRINT
3860 IF Data_reduced=1 THEN Print_files
3870 IF Run=0 THEN
3880 INPUT "Enter the date of data for for reduction (YMMDD):",Date$
3890 INPUT "Number of Zoc's connected to Multi-programmer",Zoc_number
3900 INPUT "Select data storage drive (0=,700 1=,700,0,1 2=,700,1)",Drv_case

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

3910 SELECT Drv_case
3920 CASE 0
3930     Data_drive$=":",700,0,0"
3940 CASE 1
3950     Data_drive$=":",700,0,1"
3960 CASE 2
3970     Data_drive$=":",700,1"
3980 END SELECT
3990 END IF
4000 Print_files: !
4010 PRINT "Data storage drive name => ";Data_drive$
4020 !
4030 MAT File$= (" ")
4040 FOR Zoc_case=1 TO Zoc_number !Assign files from storage to File$(*)
4050     SELECT Zoc_case
4060     CASE 1
4070         CALL File_scan(1)
4080     CASE 2
4090         CALL File_scan(2)
4100     CASE 3
4110         CALL File_scan(3)
4120     END SELECT
4130 NEXT Zoc_case
4140 !
4150 PRINT
4160 PRINT "Current files on storage disc for date ";Date$
4170 PRINT
4180 FOR Rn=1 TO Run !Print the files listing on the
4190     FOR Zn=1 TO Zoc_number !designated storage drive.
4200         FOR I=1 TO 3
4210             PRINT USING "3X,K,#";File$(Rn,(Zn-1)*3+I)
4220         NEXT I
4230         PRINT USING "/"
4240     NEXT Zn
4250 NEXT Rn
4260 !
4270 IF Drv_case<2 THEN
4280     INPUT "Do you want to copy files from the Hard drive to Floppy? (0=No 1=Yes)",Copy_h_to_f
4290     IF Copy_h_to_f=0 THEN End_view
4300     ON ERROR GOSUB View_error
4310     PRINT
4320     PRINT "WARNING: Any duplicate existing files on the Floppy will be copied over!"
4330     PRINT !Copy the files from the designated
4340     FOR Rn=1 TO Run !hard drive to the floppy drive.
4350         FOR Zn=1 TO Zoc_number
4360             FOR I=1 TO 3
4370                 Fi$=File$(Rn,(Zn-1)*3+I)
4380                 COPY Fi&Data_drive$ TO Fi&"",700,1"
4390                 IF Fi$<>" " THEN
4400                     PRINT "File ";Fi$;" copied to Floppy"
4410                 END IF
4420             NEXT I
4430         NEXT Zn
4440     NEXT Rn
4450     PRINT
4460     PRINT "Files have been copied from ";Data_drive$;" to Floppy :,700,1"
4470     END IF
4480     GOTO End_view
4490 View_error: !
4500     SELECT ERRN
4510     CASE 56 !File does not exist, then continue.
4520     CLEAR ERROR
4530     ERROR RETURN !Return to line following COPY
4540     CASE 54 !Duplicate file exist on the floppy.
4550     PURGE Fi&"",700,1" !then purge the dup file, retrun to

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

4560 CLEAR ERROR
4570 RETURN !the line COPY and copy the file.
4580 CASE ELSE
4590 DISP ERRMS
4600 PAUSE
4610 END SELECT
4620 !
4630 !
4640 End_view: !
4650 Run=0
4660 DISP "Select F2 to return to menu, or F8 to Exit"
4670 GOTO Hold
4680 !
4690 Finish: !
4700 LOAD "ZOC_MENU",10
4710 !
4720 END
4730 End: !
4740 ! Function to return todays date for input into file names
4750 DEF FNDate$(Seconds)
4760 Julian=Seconds DIV 86400-1721119
4770 Year=(4*Julian-1) DIV 146097
4780 Julian=(4*Julian-1) MOD 146097
4790 Day=Julian DIV 4
4800 Julian=(4*Day+3) DIV 1461
4810 Day=(4*Day+3) MOD 1461
4820 Day=(Day+4) DIV 4
4830 Month=(5*Day-3) DIV 153 ! Month
4840 Day=(5*Day-3) MOD 153
4850 Day=(Day+5) DIV 5 ! Day
4860 Year=100*Year+Julian
4870 IF Month<10 THEN
4880 Month=Month+3
4890 ELSE
4900 Month=Month+3
4910 Year=Year+1
4920 END IF
4930 Year$=VAL$(Year)
4940 IF Month<10 THEN
4950 Month$="0"&VAL$(Month)
4960 ELSE
4970 Month$=VAL$(Month)
4980 END IF
4990 IF Day<10 THEN
5000 Day$="0"&VAL$(Day)
5010 ELSE
5020 Day$=VAL$(Day)
5030 END IF
5040 DS=Year$(4)&Month$&Day$
5050 RETURN DS
5060 FNEED
5070 !-----
5080 ! Subroutine to build file names as required by Run number for a specified
5090 ! Zoc, and assign existing files to the File$ matrix.
5100 SUB File(Zn)
5110 COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$,Run
5120 COM /Files/ File$(*),Data_drive$
5130 DIM Data_disc1$(23),Data_disc2$(23),Data_disc3$(23)
5140 ON ERROR GOTO Error
5150 J=(Zn-1)*3
5160 Assign_file: !
5170 File1=0
5180 Data_file1$="ZW"&VAL$(Zn)&Date$&VAL$(Run)
5190 Data_disc1$=Data_file1$&Data_drive$
5200 ASSIGN @Check_path1 TO Data_disc1$ !Check for existence of ZW_

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

5210 File$(Run,J+1)=Data_file1$      !Assign ZW_ to matrix.
5220 File1=1                        !Flag to ID file exists.
5230 !
5240 File2=0
5250 Data_file2$="ZC"&VAL$(Zn)&Date$&VAL$(Run)
5260 Data_disc2$=Data_file2$&Data_drive$
5270 ASSIGN @Check_path2 TO Data_disc2$ !Check for existence of ZC_
5280 File$(Run,J+2)=Data_file2$      !Assign ZC_ to matrix.
5290 File2=1                        !Flag to ID file exists.
5300 !
5310 Data_file3$="ZR"&VAL$(Zn)&Date$&VAL$(Run)
5320 Data_disc3$=Data_file3$&Data_drive$
5330 ASSIGN @Check_path3 TO Data_disc3$ !Check for existence of ZR_
5340 File$(Run,J+3)=Data_file3$      !Assign ZR_ to matrix.
5350 !
5360 Run=Run+1                      !If ZW_ exist, reassign Run #
5370 ASSIGN @Check_path1 TO *
5380 ASSIGN @Check_path2 TO *
5390 ASSIGN @Check_path3 TO *
5400 GOTO Assign_file               !Check storage disc again.
5410 Error: ! Subroutine if ERROR=56, files donot exist for Run and Zoc
5420 IF ERRN<>56 THEN
5430   PRINT ERRMS
5440   PAUSE
5450 END IF
5460 IF File1=0 THEN Fin             !File ZW_ doesnot exist, exit
5470 IF File1=1 THEN                 !File ZW_ exists
5480   IF File2=0 THEN               !File ZC_ doesnot exists, therefore
5490     ASSIGN @Check_path1 TO *
5500     PURGE Data_disc1$           !delete ZW_
5510   ELSE
5520     Run=Run+1                   !File ZW_ & ZC_ exist, step Run
5530   END IF                       !and continue.
5540 END IF
5550 ASSIGN @Check_path1 TO *
5560 ASSIGN @Check_path2 TO *
5570 ASSIGN @Check_path3 TO *
5580 GOTO Assign_file
5590 Fin: !
5600 ASSIGN @Check_path1 TO *
5610 ASSIGN @Check_path2 TO *
5620 ASSIGN @Check_path3 TO *
5630 Data_file2$="ZC"&VAL$(Zn)&Date$&VAL$(Run)
5640 Data_file3$="ZR"&VAL$(Zn)&Date$&VAL$(Run)
5650 File$(Run,J+1)=Data_file1$      !Create ZW_ to matrix.
5660 File$(Run,J+2)=Data_file2$      !Create ZC_ to matrix.
5670 File$(Run,J+3)=Data_file3$      !Assign ZR_ to matrix.
5680 SUBEND
5690 !-----
5700 ! Subroutine to operate the HP6944A Multi-programmer for scanning Zocs.
5710 SUB Scan_zocs(Count,Pulse)
5720   COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Buffer3,Adc3,Timer
5730   Wait_time=Count*2*Pulse+10.0   ! Set Timer wait time to +10 secs.
5740   Init(Timer)                    ! Initialize Timer system
5750   Set_timeout(Timer,Wait_time)    ! Set Pause_for period of xx secs.
5760   Set_count(Timer,Count)         ! Set Count number into Timer
5770   Set_period(Timer,Pulse)        ! Set Timer pulse length in secs.
5780   Init(Buffer1)                  ! Initialize Buffer for data storage
5790   Init(Buffer2)
5800   Init(Buffer3)
5810   Start(Timer)                   ! Start data sample collection
5820   Wait_for(Timer)                ! Data samples stored in Memory System
5830 SUBEND
5840 !-----
5850 ! Subroutine to collect raw pressure data from Memory System and store

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

5860 ! onto the hard drive for future data reduction.
5870 SUB Raw_dat(Buffer,Zn)
5880   COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$,Run
5890   COM /Files/ File$(*),Data_drive$ ! Data file listing for 99 runs.
5900   ON ERROR GOTO Error
5910   INTEGER Raw_data(32672) BUFFER ! Integer raw data buffer for 32*1021
5920                                   ! data samples. Integer format for
5930                                   ! minimum transfer time to storage.
5940   DIM Data_disc$(23)
5950   Sn=Sample_number
5960   Assign_file: !
5970   Data_file$=File$(Run,(Zn-1)*3+1) ! Raw data file
5980   Data_disc$=Data_file$&Data_drive$
5990   CREATE BDAT Data_disc$,32*Sn+1,2 ! Create BDAT file of 2 byte records.
6000   ASSIGN @Data_path TO Data_disc$ ! Assign path to hard drive
6010   ASSIGN @Buffer_path TO BUFFER Raw_data(*);FORMAT OFF
6020   Input_iblock(Buffer,Raw_data(*),Sn*32,1) ! Load data samples
6030   CONTROL @Buffer_path,4;32*2*Sn+2 ! Close buffer when full
6040   TRANSFER @Buffer_path TO @Data_path ! Transfer data Data_disc
6050   ASSIGN @Buffer_path TO *
6060   ASSIGN @Data_path TO *
6070   PRINT "Raw pressure data: Run#";Run;"," Zoc#";Zn;"," storage drive file ";Data_file$&Data_drive$
6080   GOTO Fin
6090 Error: !
6100   IF ERR#<>54 THEN
6110     PRINT ERR#
6120     PAUSE
6130   END IF
6140   IF ERR#=54 THEN ! Run step routine when compiling
6150     Run=Run+1 ! multiple data runs without data
6160     CALL File(Zn) ! reduction.
6170   END IF
6180   GOTO Assign_file
6190 Fin: !
6200 SUBEND
6210 !-----
6220 ! Subroutine controls calibration mode and reads pressure from Pressure
6230 ! Standard into Zoc_cal(*) array.
6240 SUB Cal2000(Command$,I)
6250   COM /Zoc_dat/ REAL Zoc_cal1(*) BUFFER,Zoc_cal2(*) BUFFER,Zoc_cal3(*) BUFFER
6260   COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$,Run
6270   DIM Pressure$(5) ! Required to read data stream
6280   OUTPUT 9;VAL$(1);Command$;CHRS(13);END ! Sets calibrator #1 mode
6290   OUTPUT 9;VAL$(2);Command$;CHRS(13);END ! Sets calibrator #2 mode
6300   WAIT Pause_for ! Allow CALSYS2000 to stabilize
6310   FOR K=1 TO Cal_mod_id(0) ! Read CALSYS2000 cal press
6320     SELECT K
6330     CASE 1
6340       OUTPUT 9;VAL$(Cal_mod_id(1));"RP";CHRS(13);END
6350       ENTER 9 USING "#,SD.5DESZZ,K";Zoc_cal1(0,I+3),Pressure$
6360     CASE 2
6370       OUTPUT 9;VAL$(Cal_mod_id(2));"RP";CHRS(13);END
6380       ENTER 9 USING "#,SD.5DESZZ,K";Zoc_cal2(0,I+3),Pressure$
6390     CASE 3
6400       OUTPUT 9;VAL$(Cal_mod_id(3));"RP";CHRS(13);END
6410       ENTER 9 USING "#,SD.5DESZZ,K";Zoc_cal3(0,I+3),Pressure$
6420     END SELECT
6430   NEXT K
6440   IF I<=3 THEN ! Account for positive pressures used
6450     Zoc_cal1(0,I+3)=-Zoc_cal1(0,I+3) ! by CALSYS2000 in the NH,NM, & NL mode.
6460     Zoc_cal2(0,I+3)=-Zoc_cal2(0,I+3)
6470     Zoc_cal3(0,I+3)=-Zoc_cal3(0,I+3)
6480   END IF
6490 SUBEND
6500 !-----

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

6510 ! Subroutine stores calibration data collected from Memory System and
6520 ! CALSYS2000 calibration pressure data onto the hard drive.
6530 ! Zoc_cal_ is then stored onto the hard drive.
6540 SUB Cal_dat(REAL Cal(*),Zoc_cal(*) BUFFER)
6550   COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$,Run
6560   COM /Files/ File$(*),Data_drive$ ! Data file listing for 99 runs.
6570 !
6580 ! Converting Cal(*) to Zoc_cal(*)
6590   FOR J=4 TO 10           ! Cal runs: NH,NM,NL,ZO,PL,PM,PH
6600     FOR I=1 TO 32         ! Zoc ports per calibration run
6610       FOR K=0 TO 4       ! Number of samples per run
6620         Zoc_cal(I,J)=Zoc_cal(I,J)+Cal(I+K*32+(J-4)*160)
6630       NEXT K
6640       Zoc_cal(I,J)=Zoc_cal(I,J)/5 ! Average of 5 samples per port I
6650     NEXT I
6660   NEXT J
6670 !
6680 ! Transfer calibration data to hard drive.
6690   ON ERROR GOSUB Purge_file
6700   DIM Data_disc$(23)      ! Define string for data file name
6710   Zn=Zoc_cal(0,2)         ! Define Zoc number
6720   Data_file$=File$(Run,(Zn-1)*3+2) ! Calibration data file
6730   Data_disc$=Data_file$&Data_drive$
6740   CREATE BDAT Data_disc$,33,8*11 ! Create BDAT file of 11*8 byte
6750   ASSIGN @Data_path TO Data_disc$ ! Assign path to hard drive
6760   ASSIGN @Buffer_path TO BUFFER Zoc_cal(*) ;FORMAT OFF
6770   CONTROL @Buffer_path,4;8*11*33 !Set data file length
6780   TRANSFER @Buffer_path TO @Data_path!Store cal data on hard drive
6790   ASSIGN @Buffer_path TO *      ! Close path
6800   ASSIGN @Data_path TO *        ! Close path
6810   PRINT "Calibration data: Run#";Run;"", Zoc#";Zn;"", storage drive file ";Data_disc$
6820   GOTO Fin
6830 Purge_file: !
6840   IF ERR=54 THEN
6850     PRINT "Error occured in SUB Cal_dat. Error:";ERR
6860     PAUSE
6870   END IF
6880   RETURN
6890 Fin: !
6900 SUBEND
6910 !-----
6920 ! 'broutine loads raw and calibration data from the storage drive,
6930 ! reduces the data, and stores the data onto the storage drive.
6940 ! Calibration data is reduced using the Least Squares Curve fit to obtain
6950 ! coefficients for a third-order polynomial. The raw pressure data is
6960 ! reduced using these coefficients.
6970 ! Buffer arrays are replaced with standard arrays for data manipulation.
6980 ! Utilization of Buffers and the TRANSFER routine results in lost of the
6990 ! first several data bytes when data is transferred from floppy media to
7000 ! the buffer. Utilization of OUTPUT, ENTER, and arrays results in no
7010 ! data lost with floppy media. Hard disc media works well with either
7020 ! data manipulation technique using buffers or standard arrays.
7030 SUB Raw_red_dat(Zn,Rn)
7040   COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Buffer3,Adc3,Timer
7050   COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),Date$(6),Run
7060   COM /Files/ File$(*),Data_drive$ !Data file listing for 99 runs.
7070   Data_file1$=File$(Rn,(Zn-1)*3+2) ! Calibration data file
7080   Data_file2$=File$(Rn,(Zn-1)*3+1) ! Raw data file name
7090   Data_file3$=File$(Rn,(Zn-1)*3+3) ! Reduced data file name
7100   !
7110   IF Data_file3$<>"-" THEN           ! Contiru if Reduce data file
7120     GOTO Fin                       ! doesnot exist.
7130   END IF
7140   !
7150   IF Data_file1$="-" THEN

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05



```

7160     PRINT "Calibration file doesnot exist for Run#";Rn;"", Zoc#";Zn
7170     GOTO Fin
7180 END IF
7190 !
7200 ON ERROR GOSUB Error
7210 DIM Data_disc1$(23)
7220 DIM Data_disc2$(23)
7230 DIM Data_disc3$(23)
7240 Data_disc1$=Data_file1$&Data_drive$
7250 REAL Zoc_cal(32,10)           !Array to handle calibration data
7260 !
7270 Data_reduction: !
7280 PRINT "Data reduction: Run#";Rn;"", Zoc#";Zn
7290 !
7300 ASSIGN @Data_path1 TO Data_disc1$;FORMAT OFF
7310 ENTER @Data_path1;Zoc_cal(*)    !Load raw calibration data into array
7320 ASSIGN @Data_path1 TO *
7330 !
7340 ! Calibration data reduction using Least Squares Polynominal fitting.
7350 REAL A(3,3),B(3),C(3),Sum_x(6),A_inv(3,3)! Least Square reduction arrays
7360 FOR K=1 TO 32                  ! Loop for each port
7370 !
7380     MAT C= (0)
7390     MAT Sum_x= (0)
7400 !
7410     FOR J=1 TO 6                ! Routine to reduce individual port cal
7420         FOR I=4 TO 10          ! data into elements to a power x^j
7430             Sum_x(J)=Sum_x(J)+Zoc_cal(K,I)^J
7440         NEXT I
7450     NEXT J
7460 !
7470     FOR I=0 TO 3                ! Derive A array
7480         FOR J=0 TO 3
7490             A(I,J)=Sum_x(I+J)
7500         NEXT J
7510     NEXT I
7520     A(0,0)=7
7530 !
7540     FOR J=0 TO 3                ! Derive C array
7550         FOR I=4 TO 10
7560             C(J)=C(J)+Zoc_cal(K,I)^J*Zoc_cal(0,I)
7570         NEXT I
7580     NEXT J
7590 !
7600     MAT A_inv= INV(A)
7610     MAT B= A_inv*C              ! B array is matrix of Least Square
                                   coefficients a0,a1,a2,& a3 for polynomial
7620 !                               equation fitting calibration data for a
7630 !                               specified port
7640 !
7650 !
7660 ! Collect Least Square coefficients
7670     Zoc_cal(K,0)=B(0)           !Coefficient a0
7680     Zoc_cal(K,1)=B(1)           !Coefficient a1
7690     Zoc_cal(K,2)=B(2)           !Coefficient a2
7700     Zoc_cal(K,3)=B(3)           !Coefficient a3
7710 !
7720 NEXT K
7730 !
7740 ASSIGN @Data_path1 TO Data_disc1$;FORMAT OFF
7750 OUTPUT @Data_path1;Zoc_cal(*)  !Store reduced calibration data
7760 ASSIGN @Data_path1 TO *
7770 !
7780 PRINT "Calibration data reduced and transferred to ";Data_file1$
7790 !
7800 ! Recover raw data, convert to real, reduce then store in blocks

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

7810 ! of samples (32 ports scanned per block)
7820 Sn=Zoc_cal(0,1) !Sample number.
7830 INTEGER Data_integer(1:32) !Array to handle raw integer data.
7840 REAL Data_real(1:32),Data(32) !Arrays to handle raw and reduced
7850 Data_disc2S=Data_file2S&Data_driveS !real data.
7860 Data_file3S="ZR"&VALS(Zn)&DateS&VALS(Rn) !Reduced data file name.
7870 Data_disc3S=Data_file3S&Data_driveS
7880 CREATE BDAT Data_disc3S,Sn,8*33 !BDAT file of 33*8 byte records.
7890 ASSIGN @Data_path2 TO Data_disc2S;FORMAT OFF
7900 ASSIGN @Data_path3 TO Data_disc3S;FORMAT OFF
7910 !
7920 CONTROL @Data_path2,5;2 !Set read pointer to 2nd record
7930 ! !in raw interger data file.
7940 FOR Block=1 TO Sn
7950 ENTER @Data_path2;Data_integer(*) !Load raw data into array.
7960 SELECT Zoc_cal(0,2) !Translating raw interger data into
7970 CASE 1 !raw real data.
7980 Translate(Adc1,Data_integer(*),Data_real(*),
7990 CASE 2
8000 Translate(Adc2,Data_integer(*),Data_real(*))
8010 CASE 3
8020 Translate(Adc3,Data_integer(*),Data_real(*))
8030 END SELECT
8040 !
8050 ! Routine to reduce raw real data:
8060 !
8070 ! Data = a0 + a1*x + a2*x^2 + a3*x^3
8080 !
8090 ! where a0,a1,a2, & a3 are Least Square coefficients, and x is
8100 ! the individual port raw data value.
8110 !
8120 Data(0)=Block ! Store reduce data sample number.
8130 FOR K=1 TO 32
8140 Data(K)=Zoc_cal(K,0)+Zoc_cal(K,1)*Data_real(K)+Zoc_cal(K,2)*Data_real(K)^2+Zoc_cal
8150 NEXT K
8160 !
8170 OUTPUT @Data_path3;Data(*) !Store block of reduced data into
8180 NEXT Block !into the file on the designated drive.
8190 !
8200 ASSIGN @Data_path3 TO *
8210 ASSIGN @Data_path2 TO *
8220 PRINT "Raw data reduced and transferred to ";Data_file3S
8230 PRINT
8240 GOTO Fin
8250 Error: !Routine to trap error in program.
8260 PRINT ERRMS
8270 PAUSE
8280 RETURN
8290 Fin: !
8300 SUBEND
8310 !-----
8320 ! Subroutine to load existing files required by Run number for a specified
8330 ! Zoc, and assign existing files to the FileS matrix for Data reduction
8340 ! and List files routines.
8350 SUB File_scan(Zn)
8360 COM /Stats/ REAL Pulse,Sample_number,Pause_for,INTEGER Cal_mod_id(3),DateS,Run
8370 COM /Files/ FileS(*),Data_driveS
8380 DIM Data_disc1S(23),Data_disc2S(23),Data_disc3S(23)
8390 Rn=1
8400 Loop=1
8410 File_in_storage=0
8420 ON ERROR GOTO Error
8430 J=(Zn-1)*3
8440 WHILE Loop=1
8450 File1=0

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

8460      Data_file1$="ZW"&VALS(Zn)&Date$&VALS(Rn)
8470      Data_disc1$=Data_file1$&Data_drive$
8480      ASSIGN @Check_path1 TO Data_disc1$ !Check for existence of ZW_.
8490      File$(Rn,J+1)=Data_file1$          !Assign ZW_ to matrix.
8500      File1=1
8510      !
8520      Data_file2$="ZC"&VALS(Zn)&Date$&VALS(Rn)
8530      Data_disc2$=Data_file2$&Data_drive$
8540      ASSIGN @Check_path2 TO Data_disc2$ !Check for existence of ZC_.
8550      File$(Rn,J+2)=Data_file2$          !Assign ZC_ to matrix.
8560      !
8570      Data_file3$="ZR"&VALS(Zn)&Date$&VALS(Rn)
8580      Data_disc3$=Data_file3$&Data_drive$
8590      ASSIGN @Check_path3 TO Data_disc3$ !Check for existence of ZR_.
8600      File$(Rn,J+3)=Data_file3$          !Assign ZR_ to matrix.
8610      !
8620      GOTO Assign_file                    !Check storage disc again.
8630 Error: ! Subroutine if ERROR=56, files donot exist for Rn and Zoc
8640      IF ERRN<>56 THEN
8650          PRINT ERRMS
8660          PAUSE
8670      END IF
8680 Assign_file:
8690      IF File1=1 THEN                    !Switch to begin ent ring
8700          File_in_storage=1              !file names in to File$
8710      END IF
8720      IF File1=0 THEN
8730          IF File_in_storage=1 THEN      !Switch to exit routine
8740              Loop=0                     !once entries are made
8750          END IF                         !into File$
8760      END IF
8770      ASSIGN @Check_path1 TO
8780      ASSIGN @Check_path2 TO *
8790      ASSIGN @Check_path3 TO *
8800      IF Rn=100 THEN                    !Exit routine after checking
8810          Loop=0                         !up to 100 possible Run #s
8820      END IF
8830      Rn=Rn+1
8840      END WHILE
8850 Fin: !
8860      Run=Rn
8870      SUBEND
8880      !-----

```

Figure A17 (cont) ZOC-14 DAS Program: SCAN\_ZOC\_05

```

10  ! Program: READ_ZOC
20  ! Description: Reads specified data compiled from program SCAN_ZOC_04.
30  CLEAR SCREEN
40  PRINTER IS CRT
50  DIM Data_disc1$(23)
60  DIM Data_disc2$(23)
70  INPUT "Enter Zoc # (1,2,3), date (Y-M-DD), and run #:",Zoc,Date$,Run
80  INPUT "Print results to screen or printer (0=Screen 1=Printer)",View
90  IF View=1 THEN
100     PRINTER IS 711
110 ELSE
120     PRINTER IS CRT
130 END IF
140 Data_file1$="ZC"&VAL$(Zoc)&Date$&VAL$(Run)
150 Data_file2$="ZR"&VAL$(Zoc)&Date$&VAL$(Run)
160 Data_disc1$=Data_file1$&".700,0,1"
170 Data_disc2$=Data_file2$&".700,0,1"
180 ASSIGN @Data_path1 TO Data_disc1$
190 ASSIGN @Data_path2 TO Data_disc2$
200 REAL N1,N2
210 STATUS @Data_path1,3;N1           ! Determine number of records
220 STATUS @Data_path2,3;N2           ! Determine number of records
230 ALLOCATE REAL Cal(N1-1,10),Data(1:N2,32)! Define REAL array of records
240 ENTER @Data_path1;Cal(*)
250 ENTER @Data_path2;Data(*)
260 Period=Cal(0,0)
270 Hz=1/Period
280 Sample_number=Cal(0,1)
290 Zoc=Cal(0,2)
300 Print_results: !
310 PRINT "Data Print Out for Zoc #";Zoc;"", Run #";Run
320 PRINT
330 PRINT TAB(5);"Period between samples (sec):";Period
340 PRINT TAB(5);"Sample collection rate (Hz): ";Hz
350 PRINT TAB(5);"Number of samples per port: ";Sample_number
360 PRINT TAB(5);"Length of data run (sec): ";Period*31*Sample_number
370 Loop: !
380 PRINT
390 INPUT "Enter port number for data (0=Exit):",Port_number
400 IF Port_number=0 THEN Finish
410 INPUT "Enter First sample# of run to be viewed:",Sample1
420 INPUT "Enter End sample# of run:",Sample2
430 PRINT "Data Tabulation for Port #";Port_number;"from file: ";Data_file2$
440 PRINT
450 PRINT USING "K,6X,K,6X,K";"Sample","Time (sec)","Pressure (Hg.)"
460 FOR Sample=Sample1 TO Sample2
470     PRINT USING "5D,7X,2D.5D,8X,3D.5D";Sample,((Sample-1)*32+(Port_number-1))*Period,Data
480 NEXT Sample
490 GOTO Loop
500 Finish: !
510 ASSIGN @Data_path1 TO *
520 ASSIGN @Data_path2 TO *
530 DEALLOCATE Cal(*)
540 DEALLOCATE Data(*)
550 PRINT
560 PRINT
570 PRINTER IS CRT
580 LOAD "ZOC_MENU",10
590 END

```

Figure A18 ZOC-14 DAS Program: READ\_ZOC

```

10  ! Program: PLOT_DATA
20  ! Descript: Plots reduced data compiled by SCAN_ZOC_04.
30  !           Actual data points are plotted as squares. Square size
40  !           can be adjusted by varying variable Sc in line 110.
50  !
60  COM /Plot_labels/ REAL Xo,Xf,Yo,Yf,Dx,Dy,TitleS[60],X_labelS[50],Y_labelS[50]
70  !
80  CLEAR SCREEN
90  PRINTER IS CRT
100 Sc=.005                                !Scale size of plotting squares
110 PRINT "Program: PLOT_DATA"
120 PRINT
130 PRINT "Program plots the reduced data compiled by the program SCAN_ZOC_05."
140 PRINT "Hard copies of plots can be reproduced to either the HP Think Jet"
150 PRINT "printer or HP Laser Jet printer."
160 PRINT
170 PRINT
180 PRINT "Press F2 to continue after calibration display is plotted"
190 PRINT "Press <Shift> <Dump Graph> for printout of plot on the printer"
200 !
210 ! Load data -----
220 DIM Data_disc1S[23]
230 DIM Data_disc2S[23]
240 INPUT "Enter Zoc # (1,2,3), Date (Y-M-DD), Run #:",Zoc,DateS,Run
250 File_name1S="ZC"&VALS(Zoc)&DateS&VALS(Run)
260 File_name2S="ZR"&VALS(Zoc)&DateS&VALS(Run)
270 Data_disc1S=File_name1S&":.700,0,1"
280 Data_disc2S=File_name2S&":.700,0,1"
290 ASSIGN @Data_path1 TO Data_disc1S
300 ASSIGN @Data_path2 TO Data_disc2S
310 REAL N1,N2
320 STATUS @Data_path1,3;N1                ! Determine number of records
330 STATUS @Data_path2,3;N2                ! Determine number of records
340 ALLOCATE REAL Cal(N1-1,10),Data(1:N2,32)! Define REAL array of records
350 ENTER @Data_path1;Cal(*)
360 ENTER @Data_path2;Data(*)
370 Period=Cal(0,0)
380 Hz=1/Period
390 Sample_number=Cal(0,1)
400 Zoc=Cal(0,2)
410 Display_stats: !-----
420 CLEAR SCREEN
430 PRINT "Program plots reduced data from file ";File_name2S
440 PRINT
450 PRINT "Statistics for Zoc #";Zoc
460 PRINT
470 PRINT TAB(5);"Period between samples (msec):";Period*1000
480 PRINT TAB(5);"Sample collection rate (Hz): ";Hz
490 PRINT TAB(5);"Number of samples per port: ";Sample_number
500 PRINT TAB(5);"Length of data run (msec): ";((Sample_number-1)*32+31)*Period*1000
510 PRINT
520 PRINT
530 PRINT "Data point can be plotted as a continuous line, or squares."
540 PRINT
550 PRINT "Note: Wait for symbol '*' in lower right corner of CRT to change"
560 PRINT "      to a '-' before pressing <Shift><Dump Graph>"
570 !
580 INPUT "Enter Port #:",P
590 INPUT "Enter min range of pressure reading (in Hg):",Yo
600 INPUT "Enter max range of pressure reading (in Hg):",Yf
610 INPUT "Enter Start time for plot (msec):",Xo
620 INPUT "Enter Stop time for plot (msec):",Xf
630 INPUT "Enter type of data point plotting (0=Squares 1=Line):",Plot_case
640 INPUT "Plots DUMPED to Think Jet or Laser Jet: (0=TJ 1=LJ)",Dump_device
650 IF Dump_device=1 THEN

```

Figure A19 ZOC-14 DAS Program: PLOT\_DATA

```

660     DUMP DEVICE IS 9
670 ELSE
680     DUMP DEVICE IS 711
690 END IF
700 !
710 Title$="Reduced Data Plot of Port# " & VALS(P)
720 X_label$="Time (msec)"
730 Y_label$="Pressure (In Hg)"
740 Dx=10 !Tic marks per X-axis on plot
750 Dy=10 !Tic marks per Y-axis on plot
760 !
770 ! Plot routine -----
780 CALL Plot !Rountine to display graph background
790 FOR I=1 TO Sample_number !Plot Squares around data points
800     Sample_time=((Data(I,0)-1)*32+(P-1))*1000*Period
810     SELECT Plot_case
820     CASE 0
830         PLOT Sample_time,Data(I,P),-2 !Move pen to data point position
840         CALL Square(Xo,Xf,Yo,Yf,Sc) !Subroutine to plot squares
850     CASE 1
860         PLOT Sample_time,Data(I,P)
870     END SELECT
880 NEXT I
890 !
900 PAUSE
910 Finish: !-----
920 CLEAR SCREEN
930 INPUT "Graph another calibration plot: ( 0=No 1=Yes )",Again
940 IF Again=1 THEN Display_stats
950 ASSIGN @Data_path1 TO *
960 ASSIGN @Data_path2 TO *
970 DEALLOCATE Cal(*)
980 DEALLOCATE Data(*)
990 PRINTER IS CRT
1000 DUMP DEVICE IS 711
1010 LOAD "ZOC_MENU",10
1020 END
1030 !-----
1040 SUB Plot
1050 !
1060 ! Subroutine to display plot screen, less the plots of any curves
1070 ! for the specified variables in the COM /Plot_labels/ line.
1080 COM /Plot_labels/ Xo,Xf,Yo,Yf,Dx,Dy,Title$,X_label$,Y_label$
1090 CLEAR SCREEN
1100 KEY LABELS OFF
1110 GINIT !Initialize graph routine
1120 X_range=Xf-Xo !Length of X-axis
1130 Y_range=Yf-Yo !Length of Y-axis
1140 LONG 6 !Character ref pt:top center
1150 MOVE 100*RATIO/2,100 !Move cursor to screen loc for labels
1160 CSIZE 3 !Sizes labeling
1170 LABEL Title$ !Plot title
1180 MOVE 100*RATIO/2,0 !Move cursor to bottom center screen
1190 LONG 4 !Character ref pt:bottom center
1200 LABEL X_label$ !X-axis label
1210 DEG !Desig degrees for LDIR
1220 LDIR 90 !Sets Y-axis label on end
1230 LONG 6
1240 MOVE 0,50
1250 LABEL Y_label$ !Y-axis label
1260 LDIR 0 !Reset label to horizontal orientation.
1270 LONG 2 !Chr ref pt:left center
1280 VIEWPORT 10,90*RATIO,10,90 !Sets graph screen size
1290 FRAME !Box around VIEWPORT
1300 WINDOW Xo,Xf,Yo,Yf !Set axis lengths in VIEWPORT

```

Figure A19 (cont) ZOC-14 DAS Program: PLOT\_DATA

```

1310  AXES X_range/Dx,Y_range/Dy,Xo,Yo      !Axes intersect at lower left
1320  AXES X_range/Dx,Y_range/Dy,Xf,Yf      !Axes intersect at upper right
1330  GRID X_range/Dx,Y_range/Dy,Xo,Yo,Dx,Dy,.001
1340  CLIP OFF                               !So labels can print outside VIEWPORT
1350  CSIZE 3.0,.4                           !Axes label size
1360  LORG 6                                 !Number X-axis
1370  FOR I=Xo TO Xf STEP X_range/Dx
1380      MOVE I,Yo-.01*Y_range
1390      LABEL USING "#,K";I
1400  NEXT I
1410  LORG 8                                 !Number Y-axis
1420  FOR I=Yo TO Yf STEP Y_range/Dy
1430      MOVE Xo-.01*X_range,I
1440      LABEL USING "#,K";I
1450  NEXT I
1460  CLIP ON
1470  !
1480  SUBEND
1490  SUB Square(Xo,Xf,Yo,Yf,Sc)
1500  !Subroutine to plot squares around the local origin designated
1510  !by the PLOT statement.
1520      Xd=Sc*(Xf-Xo)                      !X displacement for RPLOT
1530      Yd=Sc*(Yf-Yo)*RATIO                !Y displacement for RPLOT
1540      RPLOT -Xd,Yd,-2
1550      RPLOT Xd,Yd,-1
1560      RPLOT Xd,-Yd,-1
1570      RPLOT -Xd,-Yd,-1
1580      RPLOT -Xd,Yd,2
1590  SUBEND

```

Figure A19 (cont) ZOC-14 DAS Program: PLOT\_DATA

```

10  ! Program: CAL_READ_PRI
20  ! Description: program to operate CAL2000 calibration modes sequentially
30  !               and read corresponding calibration pressures in Hg as a
40  !               test bed for later insertion into the Zoc scanning programs
50  ! Author: Rick Wendland, Naval Postgraduate School, Monterey CA
60  !       Tele:(408) 846-2165
70  !
80  CLEAR SCREEN
90  PRINTER IS CRT
100 PRINT "Program: CAL_READ_PRI"
110 PRINT
120 PRINT "  This program sequentially sets the CAL2000 calibration"
130 PRINT "  modes and reads the corresponding internal Pressure Standard"
140 PRINT "  for that mode."
150 PRINT
160 PRINT "      PH      Positive high range pressure to CAL(+)"
170 PRINT "      PM      Positive mid range pressure to CAL(+)"
180 PRINT "      PL      Positive low range pressure to CAL(+)"
190 PRINT "      ZO      CAL(+) & REF(-) connected together"
200 PRINT "      NL      Negative low range pressure to REF(-)"
210 PRINT "      NM      Negative mid range pressure to REF(-)"
220 PRINT "      NH      Negative high range pressure to REF(-)"
230 !
240 INPUT "Display results to CRT or PRINTER? (0=CRT 1=PRINTER)",Results
250 IF Results=1 THEN
260   PRINTER IS 711
270 END IF
280 CONTROL 9,5;3      !Set DTR & RTS to active for CAL2000 configuration
290 INTEGER Error,Value
300 REAL Pressure(1:7)
310 DIM Command_mode$(1:7)(2),Pressure$(5)
320 Command_mode$(1)="NH"
330 Command_mode$(2)="NM"
340 Command_mode$(3)="NL"
350 Command_mode$(4)="ZO"
360 Command_mode$(5)="PL"
370 Command_mode$(6)="PM"
380 Command_mode$(7)="PH"
390 ON ERROR GOTO Find_error
400 OUTPUT 9;"IC";CHRS(13);END      !Initialize CAL2000
410 WAIT 1.5
420 Send_command: !
430 FOR I=1 TO 7
440   OUTPUT 9;Command_mode$(I);CHRS(13);END
450   WAIT 1.5      !Wait time to allow calibrator stabilization
460   OUTPUT 9;"RP";CHRS(13);END
470   ENTER 9 USING "#,SD.5DESZZ,K";Pressure(I);Pressure$
480   GOTO No_error
490 Find_error: !
500   STATUS 9,10;Error
510   STATUS 9,6;Value
520   Error_code$=IVALS(Error,2)
530   PRINT "Register 10:      ";Error_code$(9,16)
540   PRINT "Register 6:      ";Value,CHRS(Value)
550 No_error:!
560   !DISP "F2 TO CONTINUE"      !Steps used to determine wait time between
570   !PAUSE      !CALMOD steps. ZOC output connected to the
580   NEXT I      !O-scope, use stopwatch to measure settling
590 Print_results:!      !time of dc voltage from ZOC.
600 PRINT
610 PRINT
620 PRINT "CAL2000: Calibration modes and pressures."
630 PRINT
640 PRINT USING "2X,K,5X,K";"Mode","Pressure (in Hg)"
650 PRINT

```

Figure A20 ZOC-14 DAS Program: CAL\_READ\_PRI



```
660  FOR I=1 TO 7
670    PRINT USING "3X,K,10X,3D.4D";Command_mode$(I),Pressure(I)
680  NEXT I
690 Finish: !
700  PRINTER IS CRT
710  DISP "Press F2 to continue"
720  PAUSE
730  LOAD "ZOC_MENU",10
740  END
```

Figure A20 (cont) ZOC-14 DAS Program: CAL\_READ\_PR1

```

10  ! Program: TABULATE_ZOC
20  ! Description: Tabulates data compiled from program SCAN_ZOC_04.
30  DIM Data_disc1S(23)
40  DIM Data_disc2S(23)
50  Input: !
60  CLEAR SCREEN
70  PRINT "Program tabulates Zoc pressures and calibration data from"
80  PRINT "the SCAN_ZOC_05 program."
90  INPUT "Zoc # (1,2,3), date (YMD), and run # of data to be reviewed:", Zoc, DateS, Run
100 CLEAR SCREEN
110 Data_file1S="ZC"&VALS(Zoc)&DateS&VALS(Run)
120 Data_file2S="ZR"&VALS(Zoc)&DateS&VALS(Run)
130 Data_disc1S=Data_file1S&":,700,0,1"
140 Data_disc2S=Data_file2S&":,700,0,1"
150 ASSIGN @Data_path1 TO Data_disc1S
160 ASSIGN @Data_path2 TO Data_disc2S
170 REAL N1,N2
180 STATUS @Data_path1,3,N1          ! Determine number of records
190 STATUS @Data_path2,3,N2          ! Determine number of records
200 ALLOCATE REAL C(N1-1,10)         ! Define REAL array of records
210 ALLOCATE REAL D(1:N2,32)         ! Define REAL array of records
220 ENTER @Data_path1;C(*)
230 ENTER @Data_path2;D(*)
240 !
250 INPUT "First port of calibration data to be displayed (0=Exit):", Port_o
260 IF Port_o=0 THEN Finish
270 INPUT "Last port of calibration data to be displayed:", Port_f
280 INPUT "Print results to CRT or Printer (0=CRT 1=Printer)?", Prt
290 IF Prt=0 THEN
300  PRINTER IS CRT
310 ELSE
320  PRINTER IS 711
330 END IF
340 Print_results: !
350 PRINT "Reduced Data Tabulation at a sample rate of";1/C(0,0);" Hz"
360 PRINT
370 Format1:IMAGE K,2X,K,2X,K,2X,K
380 PRINT USING Format1;"Port","Sample 1","Sample 2","Sample 3"
390 Format2:IMAGE 4D,2X,4D,3D,2X,4D,3D,2X,4D,3D
400 I=1          ! ID Data for a given sampling number
410 FOR P=Port_o TO Port_f
420  PRINT USING Format2;P,D(I,P),D(I+1,P),D(I+2,P)
430 NEXT P
440 PRINT
450 PRINT "Calibration Data Tabulation for Zoc#";Zoc
460 PRINT
470 PRINT "Pressure voltage readings:"
480 Format3:IMAGE K,4X,K,6X,K,6X,K,6X,K,6X,K,6X,K
490 PRINT USING Format3;"Port","NH","NM","NL","ZO","FL","FM","PH"
500 Format4:IMAGE 3D,X,3D,3D,X,3D,3D,X,3D,3D,X,3D,3D,X,3D,3D,X,3D,3D
510 PRINT USING Format4;0,C(0,4),C(0,5),C(0,6),C(0,7),C(0,8),C(0,9),C(0,10)
520 FOR P=Port_o TO Port_f
530  PRINT USING Format4;P,C(P,4),C(P,5),C(P,6),C(P,7),C(P,8),C(P,9),C(P,10)
540 NEXT P
550 PRINT
560 PRINT "Calibration polynomial coefficients for Zoc#";Zoc
570 Format5:IMAGE K,8X,K,16X,K,16X,K,16X,K
580 PRINT USING Format5;"Port","A0","A1","A2","A3"
590 FOR P=Port_o TO Port_f
600  PRINT P;TAB(5);C(P,0);TAB(24);C(P,1);TAB(43);C(P,2);TAB(62);C(P,3)
610 NEXT P
620 !
630 ASSIGN @Data_path1 TO *
640 ASSIGN @Data_path2 TO *
650 DEALLOCATE C(*)

```

Figure A21 ZOC-14 DAS Program: TABULATE\_ZOC

```
660 DEALLOCATE D(*)
670 !
680 INPUT "Review data or Exit (0=Exit 1=Review):",Action
690 IF Action=0 THEN Finish
700 PRINT
710 GOTO Input
720 Finish: !
730 PRINTER IS CRT
740 LOAD "ZOC_MENU",10
750 END
```

Figure A21 (cont) ZOC-14 DAS Program: TABULATE\_ZOC

```

10  ! Program: LS_PLOT
20  ! Descript: Plots calibration results and Least Square curve from
30  !           data provided by SCAN_ZOC_04
40  !
50  COM /Plot_labels/ REAL Xo,Xf,Yo,Yf,Dx,Dy,Title$(60),X_label$(50),Y_label$(50)
60  ! Input variables -----
70  CLEAR SCREEN
80  PRINT "Program: LS_PLOT"
90  PRINT
100 PRINT "Program plots the calibration curve from Least Square coefficients"
110 PRINT "and the calibration data points contain in the Calibration Data File."
120 PRINT
130 PRINT
140 PRINT "Press F2 to continue after calibration display is plotted"
150 PRINT "Press <Shift> <Dump Graph> for printout of plot on the printer"
160 INPUT "Enter Calibration Data file name:",Data_file$
170 Loop: !
180 INPUT "Enter Port #:",P
190 INPUT "Enter min range of pressure reading (in Hg):",Xo
200 INPUT "Enter max range of pressure reading (in Hg):",Xf
210 INPUT "Enter min range of Zoc voltage reading (Volts):",Yo
220 INPUT "Enter max range of Zoc voltage reading (Volts):",Yf
230 INPUT "Plots DUMPED to Think Jet or Laser Jet Printer:(0=TJ 1=LJ)",Dump_device
240 IF Dump_device=1 THEN
250     DUMP DEVICE IS 9
260 ELSE
270     DUMP DEVICE IS 711
280 END IF
290 !
300 Title$="Least Square Plot of CAL2000 Calibration (Port# "&VALS(P)&" )"
310 Y_label$="Volts"
320 X_label$="Pressure (In Hg)"
330 Dx=10 !Tic marks per X-axis on plot
340 Dy=12 !Tic marks per Y-axis on plot
350 CLEAR SCREEN
360 !
370 ! Load data -----
380 DIM Data_disc$(23)
390 Data_disc$=Data_file$&":,700,0,1" !Define data transfer path
400 ASSIGN @Data_path TO Data_disc$
410 REAL N
420 STATUS @Data_path,3:N !Determine length of data file
430 ALLOCATE REAL D(N-1,10) !Allocate an array to accept data
440 ENTER @Data_path;D(*) !Load data into memory in array D(*)
450 !
460 ! Plot routine -----
470 CALL Plot !Routine to display graph background
480 FOR X=-3 TO 3 STEP .1 !Plot calibration curve
490     Fx=(D(P,0)+D(P,1)*X+D(P,2)*X^2+D(P,3)*X^3)
500     PLOT Fx,X
510 NEXT X
520 Sc=.01 !Scale size of plotting squares
530 FOR I=4 TO 10 !Plot Squares around data points
540     PLOT D(0,I),D(P,I),-2 !Move pen to data point position
550     CALL Square(Xo,Xf,Yo,Yf,Sc) !Subroutine to plot squares
560 NEXT I
570 ASSIGN @Data_path TO *
580 !
590 PAUSE
600 CLEAR SCREEN
610 INPUT "Graph another calibration plot: ( 0=No 1=Yes )",Again
620 DEALLOCATE D(*)
630 IF Again=1 THEN Loop
640 LOAD "ZOC_MENU",10
650 END

```

Figure A22 ZOC-14 DAS Program: LS\_PLOT

```

660 !-----
670 SUB Plot
680 ! Subroutine to display plot screen, less the plots of any curves
690 ! for the specified variables in the COM /Plot_labels/ line.
700 COM /Plot_labels/ Xo,Xf,Yo,Yf,Dx,Dy,Title$,X_label$,Y_label$
710 CLEAR SCREEN
720 KEY LABELS OFF
730 GINIT                                     !Initialize graph routine
740 X_range=Xf-Xo                             !Length of X-axis
750 Y_range=Yf-Yo                             !Length of Y-axis
760 LORG 6                                     !Character ref pt:top center
770 MOVE 100*RATIO/2,100                     !Move cursor to screen loc for labels
780 CSIZE 3                                   !Sizes labeling
790 LABEL Title$                             !Plot title
800 MOVE 100*RATIO/2,0                       !Move cursor to bottom center screen
810 LORG 4                                     !Character ref pt:bottom center
820 LABEL X_label$                           !X-axis label
830 DEG                                       !Desig degrees for LDIR
840 LDIR 90                                  !Sets Y-axis label on end
850 LORG 6
860 MOVE 0,50
870 LABEL Y_label$                           !Y-axis label
880 LDIR 0                                    !Reset label to horizontal orientation.
890 LORG 2                                    !Chr ref pt:left center
900 VIEWPORT 10,90*RATIO,10,90              !Sets graph screen size
910 FRAME                                    !Box around VIEWPORT
920 WINDOW Xo,Xf,Yo,Yf                     !Set axis lengths in VIEWPORT
930 AXES X_range/Dx,Y_range/Dy,Xo,Yo        !Axes intersect at lower left
940 AXES X_range/Dx,Y_range/Dy,Xf,Yf        !Axes intersect at upper right
950 GRID X_range/Dx,Y_range/Dy,Xo,Yo,Dx,Dy,.001
960 CLIP OFF                                !So labels can print outside VIEWPORT
970 CSIZE 3.0,.4                             !Axes label size
980 LORG 6                                    !Number X-axis
990 FOR I=Xo TO Xf STEP X_range/Dx
1000   MOVE I,Yo-.01*Y_range
1010   LABEL USING "#,K";I
1020 NEXT I
1030 LORG 6                                    !Number Y-axis
1040 FOR I=Yo TO Yf STEP Y_range/Dy
1050   MOVE Xo-.01*X_range,I
1060   LABEL USING "#,K";I
1070 NEXT I
1080 CLIP ON
1090 !
1100 SUBEND
1110 SUB Square(Xo,Xf,Yo,Yf,Sc)
1120 !Subroutine to plot squares around the local origin designated
1130 !by the PLOT statement.
1140   Xd=Sc*(Xf-Xo)                           !X displacement for RPLOT
1150   Yd=Sc*(Yf-Yo)*RATIO                       !Y displacement for RPLOT
1160   RPLOT -Xd,Yd,-2
1170   RPLOT Xd,Yd,-1
1180   RPLOT Xd,-Yd,-1
1190   RPLOT -Xd,-Yd,-1
1200   RPLOT -Xd,Yd,2
1210 SUBEND

```

Figure A22 (cont) ZOC-14 DAS Program: LS\_PLOT

```

10  !Program: ZOC_MENU
20  !Description: Menu for utilization of the Zoc-14 and CALSYS 2000.
30  CLEAR SCREEN
40  CONTROL CRT,3;4
50  KEY LABELS ON
60  ON KEY 1 LABEL "SCAN 1-3ZOCs" GOTO Scan_1
70  ON KEY 2 LABEL "READ ZOCDATA" GOTO Read_z
80  ON KEY 3 LABEL "PLOT ZOCDATA" GOTO Plot
90  ON KEY 4 LABEL "READ CALSYS20" GOTO Calsys
100 ON KEY 5 LABEL "TABULATECAL DATA " GOTO Tab_data
110 ON KEY 6 LABEL "PLOT CALDATA" GOTO Plot_cal
120 ON KEY 7 LABEL "HP6944A MENU" GOTO Main
130 ON KEY 8 LABEL "EXIT MENU" GOTO Exit
140 !
150 PRINT "Zoc Electronic Pressure Module Operation Menu"
160 PRINT
170 PRINT "Item:                               Select Function Key"
180 PRINT
190 PRINT " Scan 1-3 ZOC-14 Modules (32 ports ea)      F1"
200 PRINT " Read reduced data from ZOC-14 module        F2"
210 PRINT " Plot reduced data from ZOC-14 module          F3"
220 PRINT " Read CALSYS 2000 calibration pressures         F4"
230 PRINT " Read tabulated calibration data                F5"
240 PRINT " Plot Calibration data                          F6"
250 PRINT
260 PRINT " HP6944A Main Menu                             F7"
270 PRINT " Exit Menu                                       F8"
280 !
290 Hold: !
300 GOTO Hold
310 Scan_1: !
320 CLEAR SCREEN
330 PRINT "Loading SCAN_ZOC_05"
340 LOAD BIN "/WORKSTATIONS/BIN5.1/TRANS"
350 LOAD BIN "/WORKSTATIONS/BIN5.1/SERIAL"
360 LOAD "SCAN_ZOC_05",10
370 Plot: !
380 LOAD BIN "/WORKSTATIONS/BIN5.1/GRAPHX"
390 LOAD "PLOT_DATA",10
400 Read_z: !
410 LOAD "READ_ZOC",10
420 Calsys: !
430 LOAD BIN "/WORKSTATIONS/BIN5.1/SERIAL"
440 LOAD "CAL_READ_PRI",10
450 Tab_data: !
460 LOAD "TABULATE_ZOC",10
470 Plot_cal: !
480 LOAD BIN "/WORKSTATIONS/BIN5.1/GRAPHX"
490 LOAD "LS_PLOT",10
500 Main: !
510 LOAD "HP6944A_MENU",10
520 Exit: CLEAR SCREEN
530 END

```

Figure A23 ZOC-14 DAS Program: ZOC\_MENU

## APPENDIX B. ZOC-14 PROGRAM DEVELOPMENT CHRONOLOGY

The following paragraphs provide a chronological summary of the SCAN\_ZOC program development using the HP14753A CAT Programs. First, the HP6944A manuals required the hardware configuration of the I/O cards be determined. Second, review of the interface requirements to operate the ZOC-14 units identified the binary ZOC address codes to set. The HP69730A Relay Output Card then provided the closure contacts required to set the required address codes<sup>28</sup>. The HP69759A A/D Card provided the signal conversion process to read the ZOC-14. I/O card edge connectors are fabricated from hardware supplied with the I/O cards to provide the interface between the cards and the ZOC-14. The program "SCAN\_ZOC\_01", Figure B1, provides control and reads data voltage values from the ZOC-14. SCAN\_ZOC\_01 was the simplest in the series of development programs.

"SCAN\_ZOC\_02" , Figure B2, integrated new programming features and hardware into a complete data acquisition program for utilizing one ZOC-14. The significant features were,

- ◆ segmenting the main program into "blocks" of routines
- ◆ utilizing arrays for data processing

---

<sup>28</sup> Refer to Ref. 26 for details on the Relay Output Card.

- ◆ hardware integration of the CALSYS2000
- ◆ integration of the Buffer and Timer Functions
- ◆ data reduction using Least Squares calibration curve fitting
- ◆ data storage to the hard drive using BUFFER arrays.

This program did not utilize the Zero Operate and Calibrate method. Calibration data were first collected and stored in a BUFFER array. Raw pressure data were then collected and retained in the HP69791A Memory Card. Calibration data were reduced using the Least Squares routine. The calibration data were then transferred to the hard drive calibration data file. Raw pressure data were extracted from the memory card, reduced, and stored on the hard drive reduced-pressure data file.

BUFFER arrays were used for the high speed data handling capabilities. A data transfer was initiated with a buffer and the computer executed the next line without waiting for the transfer to complete. This process allowed data transfer while the computer was performing the next command, thereby minimizing processing time.

SCAN\_ZOC\_02 did not control the CALSYS2000. Control was provided by a separate 386 desk top computer with a modem connected to the CALSYS2000 through the computer's RS-232C port. Interfacing the HP9000 with the CALSYS2000 required resolution of RS-232C data stream handling techniques.



"SCAN\_ZOC\_03", Figure B3, introduced new features. Over SCAN\_ZOC\_02, the new features were;

- ◆ the use of subroutines and the CASE statements to provide multiple ZOC-14 interfacing into the data acquisition system.
- ◆ incorporating full control of the CALSYS2000 using HP9000 commands.

The techniques to control the CALSYS2000 are discussed in section II.B.2.d.

"SCAN\_ZOC\_04", Figure B4, incorporated the following additional features,

- ◆ incorporation of a second ZOC-14 into the process to validate multiple ZOC-14 operation
- ◆ command lines to handle a second CALMOD 2000
- ◆ incorporation of the Zero Operate and Calibrate principle.

The command line to operate a second CALMOD did not interfere with the current CALSYS2000 operation since this command used an address character "2" and the installed CALMOD only responded to address character "1".

Integration of the "Zero Operate and Calibrate" principle required collecting measured pressure data followed by calibration data. This process posed a memory storage problem for multiple ZOCs. The problem was rectified by transferring the raw data to a hard drive data file for recall off-line. Three advantages were associated with this technique:

1. Programming simplification, by not having to identify raw and calibration data separately on the memory card.
2. Additional data collection capacity was made available by sequential utilization of the memory card.
3. Multiple data and calibration runs could be conducted which were limited only by the hard drive storage capacity.

Data reduction could be accomplished at any later time, providing considerable flexibility. It is to be noted, however, that sufficient space on the hard drive was required to be set aside to store the reduced data. The user must manage hard drive space when acquiring large quantities of data. Transfer of raw and calibration data to the floppy disk is one solution. This would require the user to generate a transfer program similar to the FILE\_XFER program, Figure D17, on the /UTILITY directory.

The Scan Frequency input (1-100,000 Hz) for the SCAN\_ZOC\_02, SCAN\_ZOC\_03, and SCAN\_ZOC\_04 programs was improperly implemented. The Timer Function required that a specified "Period" be input to define the length of the "step" or logic-high portion of the square wave trigger output<sup>29</sup>. The programs previous to SCAN\_ZOC\_05 used the reciprocal of the Scan Frequency as the Period to be input. This resulted in square wave periods twice the intended value. SCAN\_ZOC\_05 correctly adjusts the Scan Frequency input used to define the

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<sup>29</sup> Ref. 15 defines the input variables for the Timer Function.

Timer Function Period value, changing the input frequency range to "1-50,000 Hz". In SCAN\_ZOC\_05 the Scan Frequency input value is first inverted, then the resulting period is divided by two to obtain the Timer Period value. In the first three programs this division by two was omitted and thus the programs gave a two-fold decrease in the data sampling rate. This error was discovered during the development of the PLOT\_DATA program, Figure A20. The program plots reduced pressure data versus time for a specified ZOC port number. The detected error was detected when the plot showed only half the number of data points for the calculated time span. That SCAN\_ZOC\_05 uses the correct Timer Period value was verified by the PLOT\_DATA program.

```

10 ! Program: SCAN_ZOC_01
20 ! Description: Application program to operate HP6944A collecting voltage
30 !               readings from a ZOC using HP6944A cards.
40 !               Program provides voltage reading from a single ZOC for a
50 !               specified port number 1-32.
60 !               This program was primarily an instruction aid to learn about
70 !               HP6944A operation and ZOC operation.
80 !
90 ! Hardware: HP6944A Multi-processor
100 !           -(1) Relay Output Card (HP69730A)
110 !           -(1) 500 kHz A/D Card (HP69759A)
120 !           (1) ZOC-14 32 port Electronic Pressure Scanning Module
130 !
140 ! Notes: 1. ZOC address driven by Relay Output card connecting ZOC's
150 !           A0-A4 leads to the Relay Output card's edge connector:
160 !
170 !           ZOC      Relay Contact
180 !           A0       A
190 !           A1       C
200 !           A2       E
210 !           A3       H
220 !           A4       K
230 !
240 !           Relay Contacts 1,3,5,7, & 9 were connected together and
250 !           tied into ZOC's ground wire to complete the address circuit.
260 !           (Ref ZOC-14 Instruction Manual dwg 8329 sht 3 of 3)
270 !           2. ZOC's Output Plus lead was connected to A/D edge card
280 !           connection W, and ZOC Output Common connected to A/D Y
290 !           (Ref HP69759A Manual pg 2-3, fig. 2-1)
300 !           3. ZOC powered by OA-2 Op Amp Designer internal power supply.
310 !           4. CALSYS2000 sets the different ZOC modes through a pneumatic
320 !           switch matrix. CALSYS2000 defaults to the Zero Operate mode
330 !           when energized providing CTL2 (Pr CTL) control pressure to the
340 !           ZOC, and allow sensor pressure readings of any of the 32 ports.
350 !           5. A by-pass valve is installed between CALSYS2000 PSC and
360 !           CALMOD to minimized Nitrogen usage by closing the valve.
370 !           CALMOD is not operative until external ASCII commands are
380 !           provided via RS_232C cable to the CALMOD following CALSYS2000
390 !           energizing.
400 ! LOADSUB ALL FROM "CONFIGURE"           !These two commands must be initiated
410 ! LOADSUB ALL FROM "LIBRARY5.1"         !to append required SUB and CSUB
420 !                                       !routines to the end of this program
430 COM /Issscom/ INTEGER X(1:1106)
440 COM /Isss_heap/ Isss_heap(1000)
450 COM /Names/ Zoc_address,Zoc_pressure !Identify: Relay Output, A/D
460 Configure("Ask_me","ZOC_CONFIG_01") !Load Configuration File, and
470 !                                     !request for file review/alteration.
480 System_init                          !Initialize Relay Output and A/D
490 !
500 ! ----- BODY OF APPLICATION PROGRAM -----
510 !
520 REAL Port_reading,Port_req
530 INPUT "Enter Port # (1-32): ",Port_req !Input port #
540 Output(Zoc_address,32-Port_req)         !Select port # by Relay Output
550 Input(Zoc_pressure,Port_reading)        !Read ZOC voltage value from A/D
560 !
570 PRINT "Port #";Port_req;" reading: ";Port_reading
580 !
590 STOP
600 ! ----- END OF MAIN PROGRAM -----
610 !
620 END

```

Figure B1 Development Program: SCAN\_ZOC\_01

```

10 ! Program: SCAN_ZOC_02
20 ! Description: Application program to operate HP6944A collecting pressure
30 !               readings from one ZOC-14 32 port module using the CAL2000
40 !               to provide calibration data, reduce raw pressure data and
50 !               store data to the hard drive.
60 ! Hardware: HP6944A Multi-processor
70 !             -500 kHz A/D Card (HP69759A)
80 !             -High Speed Memory Card (HP69791A)
90 !             -Timer/Pacer Card (HP69736A)
100 !            -Counter Card (HP69775A)
110 !            CAL2000 Calibration Module
120 !            ZOC-14 32 port Electronic Pressure Scanning Module
130 ! Note: This program utilizes only one (1) Zoc Module.
140 !
150 ! Buffer Memory: 65536 16-bit data words in HP69791A
160 ! Timer: Maximum 32676 counts for one HP69775A
170 !
180 COM /Issacom/ INTEGER X(1:1106)
190 COM /Iss_heap/ Iss_heap(1000)
200 COM /Names/ Relay,Buffer,Adcl,Timer
210 Configure("Menu_off","ZOC_CONFIG_02")
220 !Configure("Ask_me","ZOC_CONFIG_02")
230 !
240 Body: ! ----- BODY OF PROGRAM -----
250 !
260 Input_variables: !----- INITIAL PARAMETERS -----
270 PRINT "Program:"
280 PRINT " - Scans a single Zoc-14 module with 32 pressure sensing ports."
290 PRINT " - Stores reduced data on the hard drive (:,700,0,1)."
300 PRINT " - CAL2000 Calibration Module used for the reference pressure standard."
310 PRINT " - Raw pressure data reduced using calibration data from CAL2000"
320 PRINT " and data from Zocs in the calibration mode."
330 PRINT
340 PRINT "Input variables: Scan frequency (1-100,000 Hz)"
350 PRINT " Samples per Port (1-1021)"
360 !
370 ! Max speed of HP system is Period=0.000002 sec. or 500 kHz.
380 !
390 PRINT
400 INPUT "Enter data rate (1-100kHz):",Hz
410 INPUT "Number of samples per port (1-1021): ",Sample_number
420 Period=1/Hz
430 PRINT
440 PRINT "Data acquisition rate: ";1/Period;" Hz"
450 PRINT "Number of samples per port: ",Sample_number
460 PRINT "Total raw data acquisition time: ",Period*Sample_number*32;" sec."
470 !
480 Cal_initial: !----- CALIBRATION SET-UP -----
490 !
500 REAL Cal(1:1120) ! Calibration collection array for
510 ! 5 samples per port, 7 calibration
520 ! runs using CAL2000.
530 REAL Zoc_cal(32,10) ! Calibration data array. Format:
540 Zoc_cal(0,0)=Period
550 Zoc_cal(0,1)=Sample_number
560 !
570 ! For ports i=1 to 32
580 ! Row 0: 0 0 0 0 NH NM NL ZO PL PM PH (pressure Hg.)
590 ! Row 1: A0 A1 A2 A3 NH NM NL ZO PL PM PH (LS coef,press volts)
600 ! LS coef are Least Squares curve fit coef for third order polynomial.
610 !
620 Calibrate=1 ! Set calibration run
630 Count=180 ! Set count to collect calibration data
640 Index=1 ! Set index for cal data collection
650 PRINT

```

Figure B2 Development Program: SCAN\_ZOC\_02

```

660 PRINT "Ensure CAL2000 is on-line and initialized"
670 PRINT
680 PRINT "Set CAL2000 calibrate mode (sequence: NH,NM,NL,ZO,PL,PM,PH)"
690 PRINT
700 Cal_routine: !-----
710 INPUT "Read RP value, and enter:",Zoc_cal(0,Index+3)
720 PRINT "Secondary Pressure Standard: ";Zoc_cal(0,Index+3)
730 !
740 Scan_zocs: !-----
750 !Note: Zoc address driven by Counter Card binary output at edge connection.
760 ! Calibration routine collects 5 samples per Zoc port.
770 ! Raw data collection follows calibration collection routine.
780 !
790 Wait_time=INT(Count*Period)+10      ! Set Timer wait time to +10 secs.
800 Init(Timer)                        ! Initialize Timer system
810 Set_timeout(Timer,Wait_time)        ! Set Wait_for period of xx secs.
820 Set_count(Timer,Count)              ! Set Count number into Timer
830 Set_period(Timer,Period)            ! Set Timer pulse length in secs.
840 Init(Buffer)                        ! Initialize Buffer for data storage
850 Start(Timer)                        ! Start data sample collection
860 Wait_for(Timer)                      ! Data samples stored in Memory System
870 !
880 ! Collect calibration data from Memory System
890 IF Calibrate=0 THEN Reduce_cal_dat
900 Input_rblock(Buffer,Cal(*),160,(Index-1)*160)! Collect cal run data
910 Index=Index+1
920 IF Index<8 THEN Cal_routine          ! Loop cal data collection runs
930 !
940 ! Collect raw data initialization
950 CLEAR SCREEN
960 PRINT "Reset Zoc mode to read pressure data"
970 DISP "Press F2 to continue"
980 PAUSE
990 CLEAR SCREEN
1000 PRINT "Collecting raw pressure data." ! Set parameters to collect raw data
1010 Calibrate=0
1020 Count=Sample_number*32              ! Set Count as function of sample number
1030                                     ! and number of port readings (32) on
1040                                     ! Zoc for raw data collection.
1050 GOTO Scan_zocs                      ! Raw data run.
1060 !
1070 ! End of Zoc scan routine
1080 Reduce_cal_dat: !----- REDUCE CALIBRATION DATA -----
1090 ! Routine to reduce Cal(*) into Zoc_cal(I,J)
1100 !
1110 REAL A(3,3),B(3),C(3),Sum_x(6),A_inv(3,3) ! Least Square reduction arrays
1120 PRINT
1130 PRINT "Reducing calibration data."
1140 FOR J=4 TO 10                        ! Cal runs: NH,NM,NL,ZO,PL,PM,PH
1150   FOR I=1 TO 32                      ! Zoc ports per calibration run
1160     FOR K=0 TO 4                      ! Number of samples per run
1170       Zoc_cal(I,J)=Zoc_cal(I,J)+Cal(I+K*32+(J-4)*160)
1180     NEXT K
1190     Zoc_cal(I,J)=Zoc_cal(I,J)/5      ! Average of 5 samples per port I
1200   NEXT I
1210 NEXT J
1220 !
1230 Least_squares: !
1240 ! Calibration data reduction using Least Squares Polynomial fitting.
1250 !
1260 FOR K=1 TO 32                        ! Loop for each port
1270 !
1280   MAT C= (0)
1290   MAT Sum_x= (0)
1300 !

```

Figure B2 (cont) Development Program: SCAN\_ZOC\_02

```

1310   FOR J=1 TO 6           ! Routine to reduce individual port cal
1320     FOR I=4 TO 10       ! data into elements to a power x^j
1330       Sum_x(J)=Sum_x(J)+Zoc_cal(K,I)^J
1340     NEXT I
1350   NEXT J
1360 !
1370   FOR I=0 TO 3           ! Derive A array
1380     FOR J=0 TO 3
1390       A(I,J)=Sum_x(I+J)
1400     NEXT J
1410   NEXT I
1420   A(0,0)=7
1430 !
1440   FOR J=0 TO 3           ! Derive C array
1450     FOR I=4 TO 10
1460       C(J)=C(J)+Zoc_cal(K,I)^J*Zoc_cal(0,I)
1470     NEXT I
1480   NEXT J
1490 !
1500   MAT A_inv= INV(A)
1510   MAT B= A_inv*C         ! B array is matrix of Least Square
1520 !                       coefficients a0,a1,a2,& a3 for polynomial
1530 !                       equation fitting calibration data for a
1540 !                       specified port
1550 !
1560   Zoc_cal(K,0)=B(0)      ! Collect Least Square coefficients
1570   Zoc_cal(K,1)=B(1)
1580   Zoc_cal(K,2)=B(2)
1590   Zoc_cal(K,3)=B(3)
1600 !
1610 NEXT K
1620 !
1630 Data_transfer: !----- TRANSFER DATA FM MEMORY SYSTEM TO HARD DISC -----
1640 ! Routine transfers data from Memory System to hard drive via buffer blocks
1650 !
1660 ! Transfer calibration data and coefficients to hard drive
1670 DIM Data_disc1$(23)      ! Define string for data file name
1680 Data_file1$="ZOC_CAL"
1690 Data_disc1$=Data_file1$&"",700,0,1"
1700 PURGE Data_disc1$
1710 CREATE BDAT Data_disc1$,33,8*11 ! Create BDAT file of 11*8 byte
1720 ASSIGN @Data_path1 TO Data_disc1$ ! Assign path to hard drive
1730 OUTPUT @Data_path1;Zoc_cal(*) ! x33 records and store on hard drive
1740 ASSIGN @Data_path2 TO * ! Close buffer path
1750 !
1760 ! Reducing raw data and transferring data to hard drive
1770 PRINT
1780 PRINT "Reducing raw pressure data and transferring data to hard drive."
1790 INTEGER Data_int(0:32) ! Extracted INTEGER raw data
1800 REAL Data_raw(0:32) ! Translated REAL raw data
1810 REAL Data_red(0:32) ! REAL reduced data
1820 REAL Data_buffer2(0:32) BUFFER ! Raw data transfer buffer
1830 REAL Data_buffer3(0:32) BUFFER ! Reduced data transfer buffer
1840 DIM Data_disc2$(23) ! Define string for data file name
1850 DIM Data_disc3$(23)
1860 REAL Nd
1870 Data_file2$="ZOC_RAW"
1880 Data_file3$="ZOC_REDUCE"
1890 Data_disc2$=Data_file2$&"",700,0,1"
1900 Data_disc3$=Data_file3$&"",700,0,1"
1910 PURGE Data_disc2$
1920 PURGE Data_disc3$
1930 CREATE BDAT Data_disc2$,10,8*33 ! Create BDAT file of 33*8 byte records
1940 ! and initial 10 records
1950 ! Each record contains one scan of the

```

Figure B2 (cont) Development Program: SCAN\_ZOC\_02

```

1960                                     ! 32 port Zoc in REAL pressure values
1970                                     ! corrected by CAL2000 values
1980 CREATE BDATA Data_disc3S,10,8*33
1990 ASSIGN @Data_path2 TO Data_disc2S ! Assign path to hard drive
2000 ASSIGN @Data_path3 TO Data_disc3S
2010 Count_inblock=32                 ! Number of samples per block transferred
2020 Block_number=Count/Count_inblock ! Number of transfer blocks
2030 !
2040 FOR Block=1 TO Sample_number      ! Loop routine to transfer data
2050     ASSIGN @Buffer_path2 TO BUFFER Data_buffer2(*);FORMAT OFF
2060     ASSIGN @Buffer_path3 TO BUFFER Data_buffer3(*);FORMAT OFF
2070     Input_iblock(Buffer,Data_int(*),Count_inblock,1)! Load data samples to
2080                                     ! buffer in blocks
2090     Translate(Adcl,Data_int(*),Data_raw(*))! Load INTEGER data into
2100                                     ! REAL data buffer array
2110 !
2120 ! Routine to reduce raw data using polynomial:
2130 !
2140 !   Data_reduce = a0 + a1*x + a2*x^2 + a3*x^3
2150 !
2160 ! where a0,a1,a2, & a3 are Least Square coefficients, and x is
2170 ! the individual port raw data value.
2180 !
2190     FOR K=1 TO 32
2200         Data_red(K)=Zoc_cal(K,0)+Zoc_cal(K,1)*Data_raw(K)+Zoc_cal(K,2)*Data_raw(K)^2+Zoc_cal(K,3)*Data_raw(K)^3
2210     NEXT K
2220 !
2230     Data_raw(0)=Period*(Block-1)      ! Store raw data sample time
2240     Data_red(0)=Period*(Block-1)      ! Store reduce data sample time
2250 !
2260     MAT Data_buffer2= Data_raw        ! Transfer raw & red data to buffer
2270     MAT Data_buffer3= Data_red
2280 !
2290     CONTROL @Buffer_path2,4;(Count_inblock+1)*8! Close REAL buffer when full
2300     CONTROL @Buffer_path3,4;(Count_inblock+1)*8
2310     TRANSFER @Buffer_path2 TO @Data_path2! Transfer data to hard drive
2320     TRANSFER @Buffer_path3 TO @Data_path3
2330     ASSIGN @Buffer_path2 TO *
2340     ASSIGN @Buffer_path3 TO *
2350 NEXT Block
2360 !
2370 STATUS @Data_path3,3;Nd             ! Determine data file length
2380 ASSIGN @Data_path2 TO *             ! Close buffer path
2390 ASSIGN @Data_path3 TO *
2400 !
2410 CLEAR SCREEN
2420 PRINT "Calibration data file: ";Data_file1S
2430 PRINT "Raw data file: ";Data_file2S
2440 PRINT "Reduced data: ";Data_file3S
2450 PRINT "Number of records (scans) in ";Data_file3S;" is: ";Nd
2460 PRINT
2470 PRINT "Use READ_ZOC to read data from ";Data_file2S;" and ";Data_file3S
2480 PRINT "Use TABULATE_ZOC to read calibration data from ";Data_file1S
2490 !
2500 Finish:
2510 DISP "Press F2 to continue."
2520 PAUSE
2530 LOAD "HP6944A_MENU",10
2540 End_body: ! ----- END OF MAIN PROGRAM -----
2550 !
2560 END

```

Figure B2 (cont) Development Program: SCAN\_ZOC\_02



```

10 ! Program: SCAN_ZOC_03
20 ! Description: Application program to operate HP6944A collecting pressure
30 !               readings from 1-3 ZOC-14 32 port modules using the CAL2000
40 !               to provide calibration data, reduce raw pressure data and
50 !               store data to the hard drive.
60 ! Hardware: HP6944A Multi-processors
70 !             -500 kHz A/D Cards (HP69759A)
80 !             -High Speed Memory Cards (HP69791A)
90 !             -Timer/Pacer Card (HP69736A)
100 !            -Counter Card (HP69775A)
110 !            CAL2000 Calibration Module
120 !            ZOC-14 32 port Electronic Pressure Scanning Modules
130 ! Notes: 1. This program utilizes up to three (3) Zoc Modules storing data
140 !         of each Zoc into a separate buffer Memory System (HP69791A).
150 !         2. COM /Names line and $DAT file ZOC_CONFIG_03 must match for this
160 !         program to operate.
170 !
180 ! Buffer Memory: 65536 16-bit data words in HP69791A per system
190 ! Timer: Maximum 32676 counts for one HP69775A
200 ! Max speed of HP system is Period=0.000002 sec. or 500 kHz.
210 !
220 COM /Issacom/ INTEGER X(1:1106)
230 COM /Iss_heap/ Iss_heap(1000)
240 COM /Names/ Buffer,Adcl,Timer
250 Configure("Menu_off","ZOC_CONFIG_03")
260 !Configure("Ask_me","ZOC_CONFIG_03")
270 !
280 Input: !----- INPUT VARIABLES -----
290 PRINT "Program: SCAN_ZOC_03"
300 PRINT " - Scans 1-3 Zoc-14 Modules (32 pressure sensing ports each)."

```

Figure B3 Development Program: SCAN\_ZOC\_03

```

660 !      Row 0:  _ _ _ _ NH NM NL ZO PL PM PH (pressure Hg.)
670 !      Row 1: A0 A1 A2 A3 NH NM NL ZO PL PM PH (LS coef, press volts)
680 !      LS coef are Least Squares curve fit coef for third order polynomial.
690 !
700 Zoc_cal(0,0)=Period
710 Zoc_cal(0,1)=Sample_number
720 Zoc_cal(0,2)=Zoc_number
730 !
740 PRINT
750 PRINT "Ensure CAL2000 is on-line, calibration pressure source at 90 psi,"
760 PRINT "and calibrator pressure cut-off valve is open (on back of CAL2000)"
770 DISP "Press F2 to start data aquisition"
780 PAUSE
790 !
800 Initial_cal: !----- CALIBRATION SET-UP -----
810 !
820 CLEAR SCREEN
830 PRINT "Collecting calibration data."
840 REAL Cal1(1120),Cal2(1120),Cal3(1120)! Calibration data array
850 REAL Cal(1120) ! SUB prog call data array
860 Count=32*5 ! Set count to collect calibration data
870 CONTROL 9,5;3 ! Set DTR & RTS to active for CAL2000
880 DIM Command_mode$(1:7)[2]
890 Command_mode$(1)="NH"
900 Command_mode$(2)="NM"
910 Command_mode$(3)="NL"
920 Command_mode$(4)="ZO"
930 Command_mode$(5)="PL"
940 Command_mode$(6)="PM"
950 Command_mode$(7)="PH"
960 OUTPUT 9;"IC";CHRS(13);END ! Initializes CAL2000
970 WAIT Wait_for ! Allows CAL2000 pressure to stabilize
980 !
990 Collect_cal_dat: !---- COLLECT RAW CALIBRATION DATA -----
1000 !
1010 ! Collect raw calibration data for each CAL2000 setting
1020 FOR Index=1 TO 7
1030 CALL Cal2000(Command_mode$(Index),Index,Wait_for)
1040 CALL Scan_zocs(Count,Period)
1050 FOR Zoc_case=1 TO Zoc_number
1060 SELECT Zoc_case
1070 CASE 1
1080 CALL Zoc_dat_cal(Buffer,Cal1(*),Index)
1090 CASE 2
1100 CALL Zoc_dat_cal(Buffer2,Cal2(*),Index)
1110 CASE 3
1120 CALL Zoc_dat_cal(Buffer3,Cal3(*),Index)
1130 END SELECT
1140 NEXT Zoc_case
1150 NEXT Index
1160 !
1170 ! Adjust Calibration pressure sign to account for CAL2000/Zoc method
1180 ! of setting negative calibration pressures.
1190 Zoc_cal(0,4)=-Zoc_cal(0,4) ! NH adjustment
1200 Zoc_cal(0,5)=-Zoc_cal(0,5) ! NM adjustment
1210 Zoc_cal(0,6)=-Zoc_cal(0,6) ! NL adjustment
1220 !
1230 CLEAR SCREEN
1240 PRINT "Calibration data collection complete."
1250 PRINT
1260 PRINT "*** Secure Calibrator pressure valve to conserve Nitrogen ***"
1270 PRINT
1280 PRINT "CAL2000 Calibration modes and pressures (in Hg):"
1290 PRINT TAB(5);"NH";TAB(15);Zoc_cal(0,4)
1300 PRINT TAB(5);"NM";TAB(15);Zoc_cal(0,5)

```

Figure B3 (cont) Development Program: SCAN\_ZOC\_03

```

1310 PRINT TAB(5);"NL";TAB(15);Zoc_cal(0,6)
1320 PRINT TAB(5);"ZO";TAB(15);Zoc_cal(0,7)
1330 PRINT TAB(5);"FL";TAB(15);Zoc_cal(0,8)
1340 PRINT TAB(5);"FM";TAB(15);Zoc_cal(0,9)
1350 PRINT TAB(5);"PH";TAB(15);Zoc_cal(0,10)
1360 !
1370 Collect_raw_dat: !--- COLLECT RAW PRESSURE DATA -----
1380 PRINT
1390 PRINT "Collecting raw pressure data." ! Set parameters to collect raw data
1400 OUTPUT 9;"IC";CHRS(13);END ! Reinitialize CAL2000
1410 WAIT Wait_for
1420 Count=Sample_number*32 ! Set Count as function of sample number
1430 ! and number of port readings (32) on
1440 ! Zoc for raw data collection.
1450 CALL Scan_zocs(Count,Period) ! Collect raw data into Memory System
1460 PRINT
1470 PRINT "Raw data collection complete."
1480 !
1490 Reduce_cal_dat: !----- REDUCE CALIBRATION DATA -----
1500 ! Routine to reduce Cal_(*) into Zoc_cal(I,J)
1510 !
1520 PRINT
1530 PRINT "Reducing calibration data."
1540 FOR Zoc_case=1 TO Zoc_number
1550 SELECT Zoc_case
1560 CASE 1
1570 CALL Zoc_dat_red(Cal1(*),1)
1580 CASE 2
1590 CALL Zoc_dat_red(Cal2(*),2)
1600 CASE 3
1610 CALL Zoc_dat_red(Cal3(*),3)
1620 END SELECT
1630 NEXT Zoc_case
1640 !
1650 Data_transfer: !----- TRANSFER DATA FM MEMORY SYSTEM TO HARD DISC -----
1660 ! Routine transfers data from Memory System to hard drive via buffer blocks
1670 !
1680 CLEAR SCREEN
1690 ! Transfer calibration data and coefficients to hard drive
1700 ON ERROR GOSUB Purge_file
1710 INPUT "Enter Calibration and Reduced Data file name ID (11 char max):",File_id$
1720 Hard_drive$=":",700,0,1"
1730 REAL Nr,Nr
1740 !
1750 !---Transfer calibration data to hard drive
1760 PRINT "Transferring calibration data to the hard drive."
1770 DIM Data_disc1$(23) ! Define string for data file name
1780 Data_file1$="ZC_"&File_id$ ! Zoc calibration file name
1790 File_name$=Data_file1$ ! Used for file purging if required
1800 Data_disc1$=Data_file1$&Hard_drive$
1810 CREATE BDAI Data_disc1$,33,8*11 ! Create BDAI file of 11*6 byte
1820 ASSIGN @Data_path1 TO Data_disc1$ ! Assign path to hard drive
1830 ASSIGN @Buffer_path1 TO BUFFER Zoc_cal(*) !Assign buffer path
1840 CONTROL @Buffer_path1,4;8*11*(Zoc_number*32+1) !Set data file length
1850 TRANSFER @Buffer_path1 TO @Data_path1 !Store cal data on hard drive
1860 STATUS @Data_path1,3;Nr ! Number of records in cal file
1870 ASSIGN @Buffer_path1 TO * ! Close path
1880 ASSIGN @Data_path1 TO * ! Close path
1890 !
1900 !---Reducing raw data and transferring data to hard drive
1910 PRINT
1920 PRINT "Reducing raw pressure data and transferring data to the hard drive."
1930 DIM Data_disc2$(23) ! Define string for data file name
1940 Data_file2$="ZR_"&File_id$ ! Reduced data file name
1950 File_name$=Data_file2$ ! Used for file purging if required

```

Figure B3 (cont) Development Program: SCAN\_ZOC\_03

```

1960 Data_disc2S=Data_file2S&Hard_driveS
1970 CREATE BDAT Data_disc2S,10,8*33 ! Create BDAT file of 33*8 byte records
1980 ! and initial 10 records
1990 ! Each record contains one scan of the
2000 ! 32 port Zoc in REAL pressure values
2010 ! corrected by CAL2000 values
2020 ASSIGN @Data_path2 TO Data_disc2S ! Assign path to hard drive
2030 !
2040 FOR Zoc_case=1 TO Zoc_number ! Collect raw data, reduce data and
2050 SELECT Zoc_case ! and store reduce data on hard drive
2060 CASE 1
2070 CALL Raw_red_dat(Buffer,1,@Data_path2)
2080 CASE 2
2090 CALL Raw_red_dat(Buffer2,2,@Data_path2)
2100 CASE 3
2110 CALL Raw_red_dat(Buffer3,3,@Data_path2)
2120 END SELECT
2130 NEXT Zoc_case
2140 !
2150 STATUS @Data_path2,3;Nd ! Reduced data file length
2160 ASSIGN @Data_path2 TO * ! Close buffer path
2170 !
2180 CLEAR SCREEN
2190 PRINT "Calibration data file: ";Data_file1S;" containing";Nr;" records."
2200 PRINT "Reduced data file: ";Data_file2S;" containing";Nd;" records."
2210 PRINT
2220 PRINT "Files ";Data_file1S;" and ";Data_file2S;" are located on hard drive ";Hard_driveS
2230 PRINT "Data reading programs available from HP6944A menu."
2240 !
2250 Finish:
2260 DISP "Press F2 to continue."
2270 PAUSE
2280 LOAD "HP6944A_MENU",10
2290 Purge_file: !
2300 IF ERR=54 THEN
2310 PURGE File_nameS&Hard_driveS
2320 END IF
2330 RETURN
2340 !
2350 END
2360 End:
-----
2370 ! Routine to operate CAL2000
2380 SUB Cal2000(CommandS,I,Wait_period)
2390 COM /Zoc_dat/ REAL Zoc_cal(96,10) BUFFER
2400 DIM PressureS(5) ! Required to read data stream
2410 OUTPUT 9;CommandS;CHRS(13);END ! Sets calibration mode
2420 WAIT Wait_period ! Allow CAL2000 to stabilize
2430 OUTPUT 9;"RP";CHRS(13);END ! Reads CAL2000 calibration pressure
2440 ENTER 9 USING "#,SD.5DESZZ,K";Zoc_cal(0,I+3),PressureS
2450 SUBEND
2460 !
-----
2470 ! Routine to operate HP6944A to collect pressure data and store in Memory
2480 !Note: -Zoc address driven by Counter Card binary output at edge connection
2490 ! through a 7404 open collector DTL/TTL located in an auxiliary box.
2500 !
2510 SUB Scan_zocs(Count,Period)
2520 COM /Names/ Buffer,Adcl,Timer
2530 Wait_time=INT(Count*Period)+10 ! Set Timer wait time to +10 secs.
2540 Init(Timer) ! Initialize Timer system
2550 Set_timeout(Timer,Wait_time) ! Set Wait_for period of xx secs.
2560 Set_count(Timer,Count) ! Set Count number into Timer
2570 Set_period(Timer,Period) ! Set Timer pulse length in secs.
2580 Init(Buffer) ! Initialize Buffer for data storage
2590 !INIT(BUFFER2)
2600 !INIT(BUFFER3)

```

Figure B3 (cont) Development Program: SCAN\_ZOC\_03

```

2610 Start(Timer)                ! Start data sample collection
2620 Wait_for(Timer)             ! Data samples stored in Memory System
2630 SUBEND
2640 !-----
2650 ! Routine to read raw calibration data from Memory System
2660 SUB Zoc_dat_cal(Buff,Cal(*),I)
2670   Input_rblock(Buff,Cal(*),160,(I-1)*160+1)
2680 SUBEND
2690 !-----
2700 ! Routine to reduce Cal_(*) into Zoc_cal(I,J)
2710 SUB Zoc_dat_red(Cal(*),Zoc)
2720   COM /Zoc_dat/ REAL Zoc_cal(96,10) BUFFER
2730   REAL A(3,3),B(3),C(3),Sum_x(6),A_inv(3,3)! Least Square reduction arrays
2740   REAL Calx(256,5)
2750   FOR J=4 TO 10                ! Cal runs: NH,NM,NL,ZO,PL,PM,PH
2760     FOR I=1 TO 32              ! Zoc ports per calibration run
2770       I1=(Zoc-1)*32+I
2780       FOR K=0 TO 4              ! Number of samples per run
2790         Zoc_cal(I1,J)=Zoc_cal(I1,J)+Cal(I+K*32+(J-4)*160)
2800         Calx(I+(J-4)*32,K+1)=Cal(I+K*32+(J-4)*160)
2810       NEXT K
2820       Zoc_cal(I1,J)=Zoc_cal(I1,J)/5 ! Average of 5 samples per port I
2830     NEXT I
2840   NEXT J
2850 !
2860   GOTO Least_squares
2870 ! Print raw calibration data
2880   PRINTER IS 711
2890   PRINT "Raw calibration data for Zoc#";Zoc
2900   PRINT
2910   Format:IMAGE 3D,2X,3D.3D,2X,3D.3D,2X,3D.3D,2X,3D.3D,2X,3D.3D
2920   FOR K=1 TO 7
2930     PRINT "RP=";K
2940     FOR J=1 TO 32
2950       I=J+(K-1)*32
2960       PRINT USING Format;J,Calx(I,1),Calx(I,2),Calx(I,3),Calx(I,4),Calx(I,5)
2970     NEXT J
2980   NEXT K
2990   PRINTER IS CRT
3000 !
3010 Least_squares:
3020 ! Calibration data reduction using Least Squares Polynomial fitting.
3030 !
3040   FOR K=1 TO 32                ! Loop for each port
3050     K1=(Zoc-1)*32+K
3060 !
3070     MAT C= (0)
3080     MAT Sum_x= (0)
3090 !
3100     FOR J=1 TO 6                ! Routine to reduce individual port cal
3110       FOR I=4 TO 10            ! data into elements to a power x^J
3120         Sum_x(J)=Sum_x(J)+Zoc_cal(K1,I)^J
3130       NEXT I
3140     NEXT J
3150 !
3160     FOR I=0 TO 3                ! Derive A array
3170       FOR J=0 TO 3
3180         A(I,J)=Sum_x(I+J)
3190       NEXT J
3200     NEXT I
3210     A(0,0)=7
3220 !
3230     FOR J=0 TO 3                ! Derive C array
3240       FOR I=4 TO 10
3250         C(J)=C(J)+Zoc_cal(K1,I)^J*Zoc_cal(0,I)

```

Figure B3 (cont) Development Program: SCAN\_ZOC\_03

```

3260     NEXT I
3270     NEXT J
3280 !
3290     MAT A_inv= INV(A)
3300     MAT B= A_inv*C           ! B array is matrix of Least Square
3310 !                           coefficients a0,a1,a2,& a3 for polynomial
3320 !                           equation fitting calibration data for a
3330 !                           specified port
3340 !
3350     Zoc_cal(K1,0)=B(0)       ! Collect Least Square coefficients
3360     Zoc_cal(K1,1)=B(1)
3370     Zoc_cal(K1,2)=B(2)
3380     Zoc_cal(K1,3)=B(3)
3390 !
3400     NEXT K
3410 SUBEND
3420 !-----
3430 SUB Raw_red_dat(Buff,Zoc,@Data_path2)
3440 ! Routine to reduce raw data using polynomial:
3450 COM /Zoc_dat/ REAL Zoc_cal(96,10) BUFFER
3460 REAL Red_data(32) BUFFER
3470 REAL Raw_data(32)
3480 COM /Stats/ REAL Period,Sample_number
3490 FOR Block=1 TO Sample_number ! Loop routine to transfer data
3500     ASSIGN @Buffer_path2 TO BUFFER Red_data(*);FORMAT OFF
3510     Input_rblock(Buff,Raw_data(*),32,1) ! Load data samples
3520     Sample_time=Block*Period
3530 !
3540 !   Red_data = a0 + a1*x + a2*x^2 + a3*x^3
3550 !
3560 ! where a0,a1,a2, & a3 are Least Square coefficients, and x is
3570 ! the individual port raw data value.
3580 !
3590     FOR K=1 TO 32
3600         K1=(Zoc-1)*32+K
3610         Red_data(K)=Zoc_cal(K1,0)+Zoc_cal(K1,1)*Raw_data(K)+Zoc_cal(K1,2)*Raw_data(K)^2+Zoc_cal(K1,3)*Raw_data(K)^3
3620     NEXT K
3630 !
3640     Red_data(0)=Sample_time ! Store reduce data sample time.
3650 !
3660     CONTROL @Buffer_path2,4;(32+1)*8 ! Close buffer when full
3670     TRANSFER @Buffer_path2 TO @Data_path2 ! Transfer data to hard drive
3680     ASSIGN @Buffer_path2 TO *
3690 NEXT Block
3700 SUBEND
3710 !-----

```

Figure B3 (cont) Development Program: SCAN\_ZOC\_03

```

10 ! Program: SCAN_ZOC_04
20 ! Description: Application program to operate HP6944A collecting pressure
30 !               readings from 1-3 ZOC-14 32 port modules using the CAL2000
40 !               to provide calibration data, reduce raw pressure data and
50 !               store data to the hard drive.
60 ! Hardware: (1) HP6944A Multi-processors
70 !           - (2) 500 kHz A/D Cards (HP69759A)
80 !           - (2) High Speed Memory Cards (HP69791A)
90 !           - (1) Timer/Pacer Card (HP69736A)
100 !          - (1) Counter Card (HP69775A)
110 !          (1) HiScan CAL2000 Calibration Module
120 !          (1) ZOC-14 32 port Electronic Pressure Scanning Modules
130 ! Notes: 1. This program utilizes up to three (3) Zoc Modules storing data
140 !         of each Zoc into a separate buffer Memory System (HP69791A).
150 !         2. COM /Names/ line and BDAT file ZOC_CONFIG_04 must match for
160 !         this program to operate.
170 !         3. HiScan requires a short period to stabilize before reading
180 !         the pressure valves. The Wait_for statement (line 340) sets this
190 !         wait period in seconds. Adjustment of the variable may be required
200 !         as additional Zocs are integrated into the Data Acquisition System.
210 !         4. HiScan currently configured for one (1) calibrator. This
220 !         program is written to operate one (1) or two (2) calibrators.
230 !
240 ! Buffer Memory: 65536 16-bit data words in HP69791A per system
250 ! Timer: Maximum 32678 counts for one HP69775A
260 ! Max speed of HP system is Period=0.000002 sec. or 500 kHz.
270 !
280 COM /Issscom/ INTEGER X(1:1106)
290 COM /Iss_heap/ Iss_heap(1000)
300 COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Timer
310 !Configure("Menu_off","ZOC_CONFIG_04")
320 !Configure("Ask_me","ZOC_CONFIG_04")
330 !
340 ! Wait_for=1.5 ! Wait time for HiScan stabilization
350 !
360 Input: !----- INPUT VARIABLES -----
370 PRINT "Program: SCAN_ZOC_04"
380 PRINT " - Scans 1-3 Zoc-14 Modules (32 pressure sensing ports each)."
390 PRINT " - Uses Zero Operate Calibrate (ZOC) principal:"
400 PRINT " - Collects raw pressure data (Zero Operate)"
410 PRINT " - Collects calibration data (Calibrate)"
420 PRINT " - Reduces raw data and stores data on hard drive : ,700,0,1"
430 PRINT " - HiScan Calibration Module used for the reference pressure standard."
440 PRINT " - Raw pressure data reduced using calibration data from HiScan"
450 PRINT " and Zocs in the calibration mode."
460 PRINT " - Program designed to operate up to three (3) Memory-A/D Cards"
470 PRINT " simultaneously. COM /Names/ line must match Multi-programmer"
480 PRINT " (HP6944A) configuration. ZOC_CONFIG_04 file must be updated"
490 PRINT " to the revised COM /Names/ line when altered."
500 PRINT
510 PRINT "Input variables: Scan frequency (1-100,000 Hz)"
520 PRINT " Samples per Port (1-1021)"
530 PRINT " Number of Zocs and their capacity"
540 PRINT " Calibration/Reduced data file name ID"
550 !
560 ! COM assigns calibration data array for 32 Zoc ports and standard values.
570 COM /Zoc_dat/ REAL Zoc_cal1(33,10) BUFFER,Zoc_cal2(33,10) BUFFER,Zoc_cal3(33,10) BUFFER
580 COM /Stats/ REAL Period,Sample_number,Wait_for,INTEGER Cal_mod_id(3)
590 MAT Zoc_cal1= (0)
600 MAT Zoc_cal2= (0)
610 MAT Zoc_cal3= (0)
620 PRINT
630 INPUT "Enter data rate (1-100kHz):",Hz
640 INPUT "Number of samples per port (1-1021): ",Sample_number
650 INPUT "Number of Zoc's connected to Multi-programmer",Zoc_number

```

Figure B4 Development Program: SCAN\_ZOC\_04

```

660 Cal_mod_id(0)=Zoc_number
670 FOR Zoc_case=1 TO Zoc_number
680     SELECT Zoc_case
690     CASE 1
700         INPUT "Enter Calibration Module number set for Zoc #1 (Enter 1 or 2):",Cal_mod_id(1)
710     CASE 2
720         INPUT "Enter Calibration Module number set for Zoc #2 (Enter 1 or 2):",Cal_mod_id(2)
730     CASE 3
740         INPUT "Enter Calibration Module number set for Zoc #3 (Enter 1 or 2):",Cal_mod_id(3)
750     END SELECT
760 NEXT Zoc_case
770 INPUT "Enter Calibration and Reduced Data file name ID (10 char max):",File_id$
780 Period=1/Hz
790 PRINT
800 PRINT "Data acquisition rate: ";TAB(50);Hz;" Hz"
810 PRINT "Number of samples per port: ";TAB(50);Sample_number
820 PRINT "Number of Zocs to be scanned: ";TAB(50);Zoc_number
830 PRINT "Total number of ports to be scanned: ";TAB(50);Zoc_number*32
840 PRINT "Total raw data acquisition time: ";TAB(50);Period*Sample_number*32;" sec."
850 PRINT "Total calibration data acquisition time: ";TAB(50);Period*5*32+(7*Wait_for);" sec."
860 !
870 Zoc_cal1(0,0)=Period
880 Zoc_cal1(0,1)=Sample_number
890 Zoc_cal1(0,2)=1
900 Zoc_cal1(0,3)=Cal_mod_id(1)
910 Zoc_cal2(0,0)=Period
920 Zoc_cal2(0,1)=Sample_number
930 Zoc_cal2(0,2)=2
940 Zoc_cal2(0,3)=Cal_mod_id(2)
950 Zoc_cal3(0,0)=Period
960 Zoc_cal3(0,1)=Sample_number
970 Zoc_cal3(0,2)=3
980 Zoc_cal3(0,3)=Cal_mod_id(3)
990 !
1000 PRINT
1010 PRINT "Ensure HiScan is on-line, calibration pressure source at 90 psi,"
1020 PRINT "and calibrator pressure cut-off valve is open (on back of HiScan)"
1030 !
1040 !
1050 CONTROL 9,5,3 ! Set DTR & RTS to active for HiScan
1060 OUTPUT 9;VALS(1);"IC";CHRS(13);END! Initialize Calibrator module #1
1070 OUTPUT 9;VALS(2);"IC";CHRS(13);END! Initialize Calibrator module #2
1080 WAIT Wait_for ! Allow HiScan to set Zocs
1090 !
1100 DISP "Press F2 to start data acquisition"
1110 PAUSE
1120 !
1130 Collect_raw_dat: !--- COLLECT RAW PRESSURE DATA -----
1140 CLEAR SCREEN
1150 PRINT
1160 PRINT "Collecting raw pressure data."
1170 Count=Sample_number*32 ! Set Count as function of sample number
1180 ! and number of port readings (32) on
1190 ! Zoc for raw data collection.
1200 CALL Scan_zocs(Count,Period) ! Collect raw data into Memory System
1210 PRINT
1220 PRINT "Raw data collection complete."
1230 BEEP
1240 !
1250 Raw_data_xfer: !----- TRANSFER RAW DATA FM MEMORY SYSTEM TO HARD DISC -----
1260 PRINT
1270 !
1280 FOR Zoc_case=1 TO Zoc_number ! Collect raw data, reduce data and
1290     SELECT Zoc_case ! and store reduce data on hard drive
1300     CASE 1

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04



```

1310     CALL Raw_dat(Buffer1,1,Sample_number)
1320     CASE 2
1330         CALL Raw_dat(Buffer2,2,Sample_number)
1340     CASE 3
1350         CALL Raw_dat(Buffer3,3,Sample_number)
1360     END SELECT
1370 NEXT Zoc_case
1380 !
1390 Initial_cal: !----- CALIBRATION SET-UP -----
1400 ! Calibration data array for each Zoc: Zoc_cal_(33 10)
1410 ! Format:
1420 !   For ports i=1 to 33
1430 !       Row 0, column 0: Period
1440 !       Row 0, column 1: Sample number
1450 !       Row 0, column 2: Zoc #
1460 !       Row 0, column 3: Calibrator module ID (1=50 psi 2=15 psi)
1470 !       Row 0:  A0 A1 A2 A3 NH NM NL ZO PL PM PH (pressure Hg.)
1480 !       Row 1:  A0 A1 A2 A3 NH NM NL ZO PL PM PH (LS coef,press volts)
1490 !       LS coef are Least Squares curve fit coef for third order polynomial.
1500 !
1510 PRINT
1520 PRINT "Collecting calibration data."
1530 REAL Cal1(1120),Cal2(1120),Cal3(1120)! Calibration data array
1540 Count=32*5                                ! Set count to collect calibration data
1550 DIM Command_mode$(1:7){2}
1560 Command_mode$(1)="NH"
1570 Command_mode$(2)="NM"
1580 Command_mode$(3)="NL"
1590 Command_mode$(4)="ZO"
1600 Command_mode$(5)="PL"
1610 Command_mode$(6)="PM"
1620 Command_mode$(7)="PH"
1630 !
1640 Collect_cal_dat: !---- COLLECT RAW CALIBRATION DATA -----
1650 !
1660 ! Collect raw calibration data for each HiScan setting
1670 FOR Index=1 TO 7
1680     CALL Cal2000(Command_mode$(Index),Index)
1690     CALL Scan_zocs(Count,Period)
1700     FOR Zoc_case=1 TO Zoc_number
1710         SELECT Zoc_case
1720         CASE 1
1730             Input_rblock(Buffer1,Cal1(*),160,(Index-1)*160+1)
1740         CASE 2
1750             Input_rblock(Buffer2,Cal2(*),160,(Index-1)*160+1)
1760         CASE 3
1770             Input_rblock(Buffer3,Cal3(*),160,(Index-1)*160+1)
1780         END SELECT
1790     NEXT Zoc_case
1800 NEXT Index
1810 !
1820 PRINT
1830 PRINT "Calibration data collection complete."
1840 BEEP
1850 WAIT .25
1860 BEEP
1870 OUTPUT 9:VAL$(1);"IC";CHRS(13);END! Initialize Calibrator module #1
1880 OUTPUT 9:VAL$(2);"IC";CHRS(13);END! Initialize Calibrator module #2
1890 PRINT
1900 PRINT "*** Secure Calibrator pressure valve to conserve Nitrogen ***"
1910 PRINT
1920 PRINT "HiScan Calibration modes and pressures (in Hg.):"
1930 Fmt1:IMAGE /,5X,K,10X,K,10X,K,10X,K
1940 PRINT USING Fmt1;"Mode","Zoc #1","Zoc #2","Zoc #3"
1950 Fmt2:IMAGE 6X,K,10X,3D,4D,8X,3D,4D,8X,3D,4D

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

```

1960 FOR I=4 TO 10
1970   PRINT USING Fmt2;Command_mode$(I-3),Zoc_cal1(0,I),Zoc_cal2(0,I),Zoc_cal3(0,I)
1980 NEXT I
1990 !
2000 Reduce_cal_dat: !----- REDUCE CALIBRATION DATA AND STORE ON HARD DRIVE -----
2010 ! Routine to reduce Cal_(*) into Zoc_cal_(I,J) and store on hard drive
2020 !
2030 PRINT
2040 PRINT
2050 PRINT "Hard drive name =>  ,700,0,1"
2060 FOR Zoc_case=1 TO Zoc_number
2070   SELECT Zoc_case
2080   CASE 1
2090     CALL Zoc_dat_red(Cal1(*),Zoc_cal1(*),File_id$)
2100   CASE 2
2110     CALL Zoc_dat_red(Cal2(*),Zoc_cal2(*),File_id$)
2120   CASE 3
2130     CALL Zoc_dat_red(Cal3(*),Zoc_cal3(*),File_id$)
2140   END SELECT
2150 NEXT Zoc_case
2160 !
2170 Reduce_data: !----- REDUCE DATA AND STORE ON HARD DRIVE -----
2180 ! Routine loads raw and calibration data from hard drive, reduces the raw
2190 ! data, and stores the reduced data to the hard drive.
2200 !
2210 FOR Zoc_case=1 TO Zoc_number
2220   SELECT Zoc_case
2230   CASE 1
2240     CALL Raw_red_dat(Zoc_cal1(*),File_id$)
2250   CASE 2
2260     CALL Raw_red_dat(Zoc_cal2(*),File_id$)
2270   CASE 3
2280     CALL Raw_red_dat(Zoc_cal3(*),File_id$)
2290   END SELECT
2300 NEXT Zoc_case
2310 !
2320 BEEP
2330 WAIT .25
2340 BEEP
2350 WAIT .25
2360 BEEP
2370 !
2380 Finish: !
2390 PRINT
2400 PRINT "Available Memory: ";SYSTEM$( "AVAILABLE MEMORY" )
2410 DISP "Press F2 to continue and return to ZOC Menu."
2420 PAUSE
2430 LOAD "ZOC_MENU",10
2440 !
2450 END
2460 End: !-----
2470 ! Routine to operate HP6944A to collect pressure data and store in Memory
2480 ! Note: -Zoc address driven by Counter Card binary output at edge connection
2490 !         through a 7404 open collector DTL/TTL located in an auxiliary box.
2500 !
2510 SUB Scan_zocs(Count,Period)
2520   COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Timer
2530   Wait_time=INT(Count*Period)+10 ! Set Timer wait time to +10 secs.
2540   Init(Timer) ! Initialize Timer system
2550   Set_timeout(Timer,Wait_time) ! Set Wait_for period of xx secs.
2560   Set_count(Timer,Count) ! Set Count number into Timer
2570   Set_period(Timer,Period) ! Set Timer pulse length in secs.
2580   Init(Buffer1) ! Initialize Buffer for data storage
2590   Init(Buffer2)
2600   !INIT(BUFFER3)

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

```

2610 Start(Timer) ! Start data sample collection
2620 Wait_for(Timer) ! Data samples stored in Memory System
2630 SUBEND
2640 !-----
2650 ! Subroutine to collect raw pressure data from Memory System and store
2660 ! onto the hard drive for future data reduction.
2670 SUB Raw_dat(Buff,Zn,Sn)
2680 ON ERROR GOSUB Purge_file
2690 INTEGER Raw_data(1:32672) BUFFER ! Integer raw data buffer for 32*1021
2700 ! data samples. Integer format for
2710 ! minimum transfer time to storage.
2720 Data_file$="ZRAW"&VALS(Zn) ! Raw data file
2730 Data_disc$=Data_file$&":700,0,1"
2740 CREATE BDAT Data_disc$,1,2 ! Create BDAT file of 2 byte records.
2750 ASSIGN @Data_path TO Data_disc$ ! Assign path to hard drive
2760 ASSIGN @Buffer_path TO BUFFER Raw_data(*);FORMAT OFF
2770 Input_iblock(Buff,Raw_data(*),Sn*32,1) ! Load data samples
2780 CONTROL @Buffer_path,4;32*2*Sn ! Close buffer when full
2790 TRANSFER @Buffer_path TO @Data_path ! Transfer data to hard drive
2800 ASSIGN @Buffer_path TO *
2810 ASSIGN @Data_path TO *
2820 PRINT "Raw pressure data for Zoc #";Zn;" transferred to the hard drive file ";Data_file$
2830 GOTO Fin
2840 Purge_file: !
2850 IF ERRN=54 THEN
2860 PURGE Data_disc$
2870 END IF
2880 RETURN
2890 Fin: !
2900 SUBEND
2910 !-----
2920 ! Subroutine controls calibration mode and reads pressure from Pressure
2930 ! Standard into Zoc_cal(*) array.
2940 SUB Cal2000(Command$,I)
2950 COM /Zoc_dat/ REAL Zoc_cal1(*) BUFFER,Zoc_cal2(*) BUFFER,Zoc_cal3(*) BUFFER
2960 COM /Stats/ REAL Period,Sample_number,Wait_for,INTEGER Cal_mod_id(3)
2970 DIM Pressure$(5) ! Required to read data stream
2980 OUTPUT 9;VALS(1);Command$;CHRS(13);END ! Sets calibrator #1 mode
2990 OUTPUT 9;VALS(2);Command$;CHRS(13);END ! Sets calibrator #2 mode
3000 WAIT Wait_for ! Allow HiScan to stabilize
3010 FOR K=1 TO Cal_mod_id(0) ! Read HiScan cal press
3020 SELECT K
3030 CASE 1
3040 OUTPUT 9;VALS(Cal_mod_id(1));"RP";CHRS(13);END
3050 ENTER 9 USING "#,SD.SDESZZ,K";Zoc_cal1(0,I+3),Pressure$
3060 CASE 2
3070 OUTPUT 9;VALS(Cal_mod_id(2));"RP";CHRS(13);END
3080 ENTER 9 USING "#,SD.SDESZZ,K";Zoc_cal2(0,I+3),Pressure$
3090 CASE 3
3100 OUTPUT 9;VALS(Cal_mod_id(3));"RP";CHRS(13);END
3110 ENTER 9 USING "#,SD.SDESZZ,K";Zoc_cal3(0,I+3),Pressure$
3120 END SELECT
3130 NEXT K
3140 IF I<=3 THEN ! Account for positive pressures used
3150 Zoc_cal1(0,I+3)--Zoc_cal1(0,I+3) ! by HiScan in the NH,NM, & NL mode.
3160 Zoc_cal2(0,I+3)--Zoc_cal2(0,I+3)
3170 Zoc_cal3(0,I+3)--Zoc_cal3(0,I+3)
3180 END IF
3190 SUBEND
3200 !-----
3210 ! Subroutine reduces calibration data collected from Memory System and
3220 ! HiScan calibration pressure data into a Third-order polynomial curve
3230 ! fit using the Least Squares routine. The complete calibration array
3240 ! Zoc_cal_ is then stored onto the hard drive.
3250 SUB Zoc_dat_red(REAL Cal(*),Zoc_cal(*) BUFFER,F_id$)

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

```

3260 REAL A(3,3),B(3),C(3),Sum_x(6),A_inv(3,3)! Least Square reduction arrays
3270 !
3280 ! Converting Cal(*) to Zoc_cal(*)
3290 FOR J=4 TO 10 ! Cal runs: NH,NM,NL,ZO,PL,PM,PH
3300 FOR I=1 TO 32 ! Zoc ports per calibration run
3310 FOR K=0 TO 4 ! Number of samples per run
3320 Zoc_cal(I,J)=Zoc_cal(I,J)+Cal(I+K*32+(J-4)*160)
3330 NEXT K
3340 Zoc_cal(I,J)=Zoc_cal(I,J)/5 ! Average of 5 samples per port I
3350 NEXT I
3360 NEXT J
3370 !
3380 ! Calibration data reduction using Least Squares Polynomial fitting.
3390 FOR K=1 TO 32 ! Loop for each port
3400 !
3410 MAT C= (0)
3420 MAT Sum_x= (0)
3430 !
3440 FOR J=1 TO 6 ! Routine to reduce individual port cal
3450 FOR I=4 TO 10 ! data into elements to a power x^j
3460 Sum_x(J)=Sum_x(J)+Zoc_cal(K,I)^J
3470 NEXT I
3480 NEXT J
3490 !
3500 FOR I=0 TO 3 ! Derive A array
3510 FOR J=0 TO 3
3520 A(I,J)=Sum_x(I+J)
3530 NEXT J
3540 NEXT I
3550 A(0,0)=7
3560 !
3570 FOR J=0 TO 3 ! Derive C array
3580 FOR I=4 TO 10
3590 C(J)=C(J)+Zoc_cal(K,I)^J*Zoc_cal(0,I)
3600 NEXT I
3610 NEXT J
3620 !
3630 MAT A_inv= INV(A)
3640 MAT B= A_inv*C ! B array is matrix of Least Square
3650 ! coefficients a0,a1,a2,& a3 for polynomial
3660 ! equation fitting calibration data for a
3670 ! specified port
3680 !
3690 ! Collect Least Square coefficients
3700 Zoc_cal(K,0)=B(0)
3710 Zoc_cal(K,1)=B(1)
3720 Zoc_cal(K,2)=B(2)
3730 Zoc_cal(K,3)=B(3)
3740 !
3750 NEXT K
3760 !
3770 ! Transfer calibration data to hard drive.
3780 ON ERROR GOSUB Purge_file
3790 DIM Data_disc$(23) ! Define string for data file name
3800 Data_file$="ZC"&VALS(Zoc_cal(0,2))&"_ "&F_id$ ! Zoc calibration file name
3810 Data_disc$=Data_file$&"",700,0,1"
3820 CREATE BDAT Data_disc$,33,8*11 ! Create BDAT file of 11*8 byte
3830 ASSIGN @Data_path TO Data_disc$ ! Assign path to hard drive
3840 ASSIGN @Buffer_path TO BUFFER Zoc_cal(*) ;FORMAT OFF
3850 CONTROL @Buffer_path,4;8*11*33 !Set data file length
3860 TRANSFER @Buffer_path TO @Data_path!Store cal data on hard drive
3870 ASSIGN @Buffer_path TO * ! Close path
3880 ASSIGN @Data_path TO * ! Close path
3890 PRINT "Calibration data for Zoc #";Zoc_cal(0,2);" transfer to the hard drive file ";Data_file$
3900 GOTO Fin

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

```

3910 Purge_file: !
3920 IF ERRN=54 THEN
3930 PURGE Data_disc$
3940 END IF
3950 RETURN
3960 Fin: !
3970 SUBEND
3980 !-----
3990 ! Subroutine loads raw data from the hard drive, reduces the data using
4000 ! calibration coefficients, and stores the reduced data onto the hard drive
4010 SUB Raw_red_dat(REAL Zoc_cal(*) BUFFER,F_id$)
4020 COM /Names/ Buffer1,Adc1,Buffer2,Adc2,Timer
4030 INTEGER Data_integer(1:32) BUFFER
4040 REAL Data_real(1:32),Data(32) BUFFER
4050 DIM Data_file2$(23)
4060 ON ERROR GOSUB Purge_file
4070 Data_file1$="ZRAW"&VAL$(Zoc_cal(0,2))
4080 Data_disc1$=Data_file1$&":700,0,1"
4090 Data_file2$="ZR"&VAL$(Zoc_cal(0,2))&"_ "&F_id$
4100 Data_disc2$=Data_file2$&":700,0,1"
4110 CREATE BDAT Data_disc2$,1,8*33 ! Create BDAT file of 33*8 byte records.
4120 ASSIGN @Data_path1 TO Data_disc1$
4130 ASSIGN @Data_path2 TO Data_disc2$
4140 CONTROL @Data_path1,5;2 !Set read pointer to first data byte
4150 !
4160 ! Recover raw data, convert to real, reduce then store in blocks
4170 ! of samples (32 ports scanned per block)
4180 FOR Block=1 TO Zoc_cal(0,1)
4190 ASSIGN @Buffer_path1 TO BUFFER Data_integer(*);FORMAT OFF
4200 TRANSFER @Data_path1 TO @Buffer_path1;COUNT 32*2
4210 CONTROL @Buffer_path1,4;32*2
4220 SELECT Zoc_cal(0,2)
4230 CASE 1
4240 Translate(Adc1,Data_integer(*),Data_real(*))
4250 CASE 2
4260 Translate(Adc2,Data_integer(*),Data_real(*))
4270 CASE 3
4280 END SELECT
4290 !
4300 ! Routine to reduce raw data using polynomial:
4310 !
4320 ! Data = a0 + a1*x + a2*x^2 + a3*x^3
4330 !
4340 ! where a0,a1,a2, & a3 are Least Square coefficients, and x is
4350 ! the individual port raw data value.
4360 !
4370 Sample_time=Zoc_cal(0,0)*(Block-1)
4380 Data(0)=Sample_time ! Store reduce data sample time.
4390 FOR K=1 TO 32
4400 Data(K)=Zoc_cal(K,0)+Zoc_cal(K,1)*Data_real(K)+Zoc_cal(K,2)*Data_real(K)^2+Zoc_cal(K,3)*Data_real(K)^3
4410 NEXT K
4420 !
4430 ASSIGN @Buffer_path2 TO BUFFER Data(*)
4440 CONTROL @Buffer_path2,4;8*33
4450 TRANSFER @Buffer_path2 TO @Data_path2
4460 ASSIGN @Buffer_path2 TO *
4470 NEXT Block
4480 !
4490 ASSIGN @Data_path1 TO *
4500 ASSIGN @Data_path2 TO *
4510 ASSIGN @Buffer_path1 TO *
4520 PRINT "Reduced data file for Zoc #";Zoc_cal(0,2);" transfer to the hard drive file ";Data_file2$
4530 GOTO Fin
4540 Purge_file: !
4550 IF ERRN=54 THEN

```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

```
4560      PURGE Data_disc2S
4570      END IF
4580      RETURN
4590 Fin:  !
4600 SUBEND
4610 !-----
```

Figure B4 (cont) Development Program: SCAN\_ZOC\_04

## APPENDIX C. DATA FILE MANAGEMENT

SCAN\_ZOC\_05 generates a large number of data files in a short period of time. During program development, it was desirable to purge these files from the "DATA" hard drive ":",700,0,1" to keep track of useable files and remove unwanted files. The utility program "PURGE\_PROG", Figure C1, was developed to purge SCAN\_ZOC\_05-generated data files from the hard drive. This program can be used when known bad data has been collected and it is desirable to purge these files from the hard drive.

PURGE\_PROG is located on the UTILITY directory (Figure D1). It is loaded into RAM from any directory and run by typing,

1. LOAD "/UTIL/PURGE\_PROG", followed by depressing the <Enter> key to load the program into the RAM.
2. RUN, followed by the <Enter> key to execute the program.

The program executes a CAT command and displays the hard drive files as illustrated in Figure C2. The program prompts the user for the date (YMMDD), the first run number, and last run number of consecutive data files to be purged. Program actions are displayed on the screen. The program prompts the user to purge more files or to re-display the remaining files

using the CAT command. If file re-display (2=CAT) is selected, the program prompts again for the date and run numbers. Entering <0,0,0> will exit the program.



```

10  !Program to purge designated files from SCAN_ZOC_05
20  CLEAR SCREEN
30  ON ERROR GOTO Cont
40  Drive$=":",700,0,1"
50  Input1: !
60  CAT Drive$;SELECT "Z"
70  PRINT
80  Input2: !
90  INPUT "Enter date (YMTDD), begin run#, end run# (0,0,0=Exit)",Date$,Run0,Run1
100 IF Run0=0 THEN Fin
101 FOR Zoc=1 TO 3
102   FOR Run=Run0 TO Run1
110    File1$="ZW"&VALS(Zoc)&Date$&VALS(Run)
120    File2$="ZC"&VALS(Zoc)&Date$&VALS(Run)
130    File3$="ZR"&VALS(Zoc)&Date$&VALS(Run)
140   Purge1: !
150    PURGE File1$&Drive$
160    PRINT "Purged file: ";File1$
170   Purge2: !
180    PURGE File2$&Drive$
190    PRINT "Purged file: ";File2$
200   Purge3: !
210    PURGE File3$&Drive$
220    PRINT "Purged file: ";File3$
230    GOTO Next
240   Cont: !
250    IF ERRN=56 THEN
260      SELECT ERRLN
270      CASE 150
280        GOTO Purge2
290      CASE 180
300        GOTO Purge3
310      CASE 210
320        GOTO Next
330      END SELECT
340    END IF
350    RETURN
360   Next: !
370    NEXT Run
380  NEXT Zoc
390 Print: !
400 PRINT
410 INPUT "Purge more? (0=No 1=Yes 2=CAT)",Act
420 IF Act=1 THEN Input2
430 IF Act=2 THEN Input1
440 Fin: !
450 LOAD "ZOC_MENU",10
460 END

```

Figure C1 TPL Program: PURGE\_PROG

.,700,0,1

VOLUME LABEL: DATA

FILE NAME	PRO	TYPE	REC/FILE	BYTE/REC	ADDRESS	DATE	TIME
ZW1205161		BDAT	97	2	592	16-May-92	14:54
ZW2205161		BDAT	97	2	594	16-May-92	14:54
ZW3205161		BDAT	97	2	596	16-May-92	14:54
ZC1205161		BDAT	33	88	598	16-May-92	14:55
ZC2205161		BDAT	33	88	611	16-May-92	14:55
ZC3205161		BDAT	33	88	624	16-May-92	14:55
ZR1205161		BDAT	3	264	637	16-May-92	14:55
ZR2205161		BDAT	3	264	642	16-May-92	14:55
ZR3205161		BDAT	3	264	647	16-May-92	14:55

Figure C2 Hard Drive Sample Listing of ZOC-14 DAS Data Files

## APPENDIX D. TPL PROGRAMS

A selection of programs generated for use at TPL are documented in this Appendix. The programs are found in individual directories according to their specific function or purpose. Figure D1 displays the major directories and the associated programs. Each directory is identified by the forward slash character "/", followed by the directory name, and a colon, followed by the system drive name "CS80:,700". Subdirectories are identified by the FILE TYPE "DIR". BASIC programs are identified by the FILE TYPE "PROG".

"AUTOST", Figure D2, is the HP9000 initialization program located in directory "/WORKSTATIONS". This program is called by the BASIC system during boot-up. AUTOST is used to display the Main Menu and define the function keys used to select the Sub Menus and associated programs in the HP9000 Data Acquisition System.

Turbocharger performance mapping programs (prepared for student laboratories) are listed in Figures D3-D6. The program "SCAN\_TEMP", Figure D7, is used to monitor temperature probes. SCAN\_TEMP, as listed, monitors temperature probe outputs from the Turbocharger Test Cell. "TURBO\_MENU", Figure D8, is used to select the turbocharger the above programs (Figures D3-D7).

Turbomachinery design programs used in the course AE 4431 are listed in Figures D9-D13.

Program "SCAN", Figure D14, is used to operate the HG-78K Scanivalve Controller, HP3495A Scanner, HP3456A Digital Voltmeter, and records Scanivalve transducers. SCAN and SCAN\_TEMP programs, located in directory /WORK/DEVICE\_PROG, are used in the majority of programs required for data acquisition at TPL.

The sub-program "Plot", Figure D15, is appended to the end of programs used to display plots on the HP9000 CRT, or for generating plots on the various plotters.

The sub-program "FNDate\$", Figure D16, is a user-defined function to calculate numbered values for the date in the format year, month, and day. FNDate\$ is in sub-program "Date\_func", which is located in the directory /WORK/FUNCTION\_PROG.

"FILE\_XFER", Figure D17, is a utility program used for file transfer and "purging" on the HP9000. FILE\_XFER is located in the /UTIL directory.

The program "MAIN\_MENU", Figure D18, is used to quickly restore the CRT screen to its system display and call-up the Main Menu screen. The program is located in the root directory /. Loading and executing MAIN\_MENU is accomplished by entering the following command on the HP9000, and executing the command by depressing the Enter key:

```
LOAD "/MAIN_MENU",10 <Enter>
```

/WORKSTATIONS:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23328

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
BIN5.1	DIR	21	32	17-Jan-92	14:25	RWXRWXRX	18	9
STUDENT_DIARY	DIR	87	32	14-Apr-92	17:41	RWXRWXRX	18	9
AUTOST	PROG	11	256	29-Apr-92	15:32	RW-RW-RW-	18	9
DIRECTORY_INFO	PROG	34	256	30-Apr-92	15:11	RW-RW-RW-	18	9

/TURBINE:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23328

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
TURBO2	PROG	14	256	1-Oct-91	17:40	RW-RW-RW-	18	9
TURBO3	PROG	14	256	1-Oct-91	17:43	RW-RW-RW-	18	9
TURBO4	PROG	34	256	16-Oct-91	16:01	RW-RW-RW-	18	9
TURBO1	PROG	45	256	21-Oct-91	7:59	RW-RW-RW-	18	9
TURBO_MENU	PROG	7	256	29-Apr-92	15:52	RW-RW-RW-	18	9
SCAN_TEMP	PROG	8	256	30-Apr-92	7:55	RW-RW-RW-	18	9
TURBO_BAK	DIR	4	32	20-Apr-92	13:49	RWXRWXRX	18	9

/HP6944A:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
fp_data	BDAT	18	256	3-Jan-92	7:52	RW-RW-RW-	18	9
CARD_TEST	PROG	444	256	3-Jan-92	7:52	RW-RW-RW-	18	9
CONFIGURE	PROG	127	256	3-Jan-92	7:53	RW-RW-RW-	18	9
LIBRARY_5	PROG	888	256	3-Jan-92	7:54	RW-RW-RW-	18	9
VERIFY	PROG	282	256	3-Jan-92	8:02	RW-RW-RW-	18	9
menu_data	BDAT	71	256	3-Jan-92	12:20	RW-RW-RW-	18	9
MENUER	PROG	136	256	3-Jan-92	13:40	RW-RW-RW-	18	9
FRONT_P	PROG	174	256	3-Jan-92	13:41	RW-RW-RW-	18	9
HP6944A_BAK	DIR	8	32	30-Apr-92	12:57	RWXRWXRX	18	9
TABULATE_ZOC	PROG	13	256	26-Apr-92	15:40	RW-RW-RW-	18	9
READ_ZOC	PROG	11	256	26-Apr-92	17:30	RW-RW-RW-	18	9
SCAN_ZOC_05	PROG	1148	256	30-Apr-92	13:02	RW-RW-RW-	18	9
CAL_READ_PR1	PROG	12	256	30-Apr-92	13:49	RW-RW-RW-	18	9
LS_PLOT	PROG	22	256	30-Apr-92	14:33	RW-RW-RW-	18	9
DOCUMENT	PROG	59	256	13-Apr-92	8:45	RW-RW-RW-	18	9
VER_CFG	BDAT	6	256	24-Apr-92	16:51	RW-RW-RW-	18	9
HP6944A_MENU	PROG	7	256	7-Apr-92	7:18	RW-RW-RW-	18	9
DEVELOPMENT	DIR	11	32	30-Apr-92	15:07	RWXRWXRX	18	9
PLOT_DATA	PROG	29	256	30-Apr-92	14:18	RW-RW-RW-	18	9
ZOC_CONFIG_05	BDAT	5	256	26-Apr-92	16:53	RW-RW-RW-	18	9
ZOC_MENU	PROG	9	256	24-Apr-92	12:55	RW-RW-RW-	18	9

Figure D1 Listing of TPL Programs by Directory

/DESIGN:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
DESIGN_BAK	DIR	4	32	30-Apr-92	8:07	RWXRWXRWX	18	9
DESIGN_MENU	PROG	8	256	16-Dec-91	16:41	RW-RW-RW-	18	9
R_4431T	PROG	21	256	16-Dec-91	13:59	RW-RW-RW-	18	9
A_4431T	PROG	21	256	16-Dec-91	14:01	RW-RW-RW-	18	9
TURB3	PROG	29	256	17-Dec-91	14:32	RW-RW-RW-	18	9
TURB4	PROG	38	256	20-Dec-91	16:42	RW-RW-RW-	18	9

/WORK:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
FUNCTION_PROG	DIR	12	32	20-Apr-92	14:35	RWXRWXRWX	18	9
DEVICE_PROG	DIR	22	32	30-Apr-92	15:29	RWXRWXRWX	18	9
DISCREP_DOC	PROG	5	256	30-Dec-91	11:59	RW-RW-RW-	18	9

/WORK/DEVICE\_PROG:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
CAL	PROG	7	256	20-Apr-92	14:15	RW-RW-RW-	18	9
CAL_READ_FR	PROG	11	256	20-Apr-92	14:16	RW-RW-RW-	18	9
SET_BRIDGE	PROG	6	256	20-Apr-92	14:16	RW-RW-RW-	18	9
READ_PORT	PROG	5	256	20-Apr-92	14:16	RW-RW-RW-	18	9
SCAN_PORT	PROG	4	256	20-Apr-92	14:17	RW-RW-RW-	18	9
BCD_CONVERT	PROG	4	256	20-Apr-92	14:17	RW-RW-RW-	18	9
SCAN_TEMP	PROG	8	256	20-Apr-92	14:18	RW-RW-RW-	18	9
UNPACK	PROG	4	256	20-Apr-92	14:23	RW-RW-RW-	18	9
HP37_PACK	PROG	5	256	20-Apr-92	14:23	RW-RW-RW-	18	9
HP37_BENCH	PROG	7	256	20-Apr-92	14:24	RW-RW-RW-	18	9
HP37_BCD	PROG	2	256	20-Apr-92	14:24	RW-RW-RW-	18	9
HP37-56	PROG	3	256	20-Apr-92	14:24	RW-RW-RW-	18	9
HP56_PACK	PROG	7	256	20-Apr-92	14:24	RW-RW-RW-	18	9
HP37_EXT1	PROG	4	256	20-Apr-92	14:24	RW-RW-RW-	18	9
HP56SRQ	PROG	3	256	20-Apr-92	14:26	RW-RW-RW-	18	9
HP56MEM	PROG	5	256	20-Apr-92	14:26	RW-RW-RW-	18	9
HP37_EXT2	PROG	4	256	20-Apr-92	14:26	RW-RW-RW-	18	9
HP37_A(*)	PROG	3	256	20-Apr-92	14:26	RW-RW-RW-	18	9
HP37_GRAPH	PROG	12	256	20-Apr-92	14:27	RW-RW-RW-	18	9
HP37_INT	PROG	12	256	20-Apr-92	14:27	RW-RW-RW-	18	9
SCAN	PROG	11	256	27-Apr-92	14:13	RW-RW-RW-	18	9
OUTPUT_9	PROG	5	256	30-Apr-92	15:29	RW-RW-RW-	18	9

Figure D1 (cont) Listing of TPL Programs by Directory

/WORK/FUNCTION\_PROG:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
GRAPH	PROG	9	256	20-Apr-92	14:20	RW-RW-RW-	18	9
GRAPH_PLOTTER	PROG	6	256	20-Apr-92	14:20	RW-RW-RW-	18	9
Plot	PROG	10	256	20-Apr-92	14:20	RW-RW-RW-	18	9
Date_func	PROG	4	256	20-Apr-92	14:20	RW-RW-RW-	18	9
Square	PROG	4	256	20-Apr-92	14:21	RW-RW-RW-	18	9
BUFF1	PROG	9	256	20-Apr-92	14:21	RW-RW-RW-	18	9
LEAST SQUARE	PROG	6	256	20-Apr-92	14:21	RW-RW-RW-	18	9
LS_TEST	PROG	18	256	20-Apr-92	14:21	RW-RW-RW-	18	9
LS_PLOT1	PROG	17	256	20-Apr-92	14:21	RW-RW-RW-	18	9
TEST	BDAT	4	256	20-Apr-92	14:22	RW-RW-RW-	18	9
DATA LOGGIN	PROG	4	256	20-Apr-92	14:22	RW-RW-RW-	18	9
STOPWATCH	PROG	4	256	20-Apr-92	14:23	RW-RW-RW-	18	9

/UTIL:CS80, 700

LABEL:

FORMAT: HFS

AVAILABLE SPACE: 23528

FILE NAME	FILE TYPE	NUM RECS	REC LEN	MODIFIED DATE	TIME	PERMISSION	OWNER	GROUP
VERIFY	PROG	153	256	31-Jul-91	16:34	RW-RW-RW-	18	9
HPIB_CHECK	PROG	4	256	9-Aug-91	9:03	RW-RW-RW-	18	9
BACKUP	PROG	397	256	23-Aug-91	14:03	RW-RW-RW-	18	9
RETURN_MAIN	PROG	2	256	20-Apr-92	14:34	RW-RW-RW-	18	9
MAIN_MENU	PROG	2	256	20-Apr-92	16:02	RW-RW-RW-	18	9
PURGE_PROG	PROG	6	256	26-Apr-92	15:49	RW-RW-RW-	18	9
COPY_FILES	PROG	4	256	30-Apr-92	7:45	RW-RW-RW-	18	9
FILE_XFER	PROG	6	256	30-Apr-92	8:20	RW-RW-RW-	18	9
LASERJET	PROG	3	256	30-Apr-92	15:58	RW-RW-RW-	18	9

Figure D1 (cont) Listing of TPL Programs by Directory

```

10  !Program: AUTOST
20  !Description: Program is loaded immediately following system boot-up
30  !              providing an initial User to Computer interface through
40  !              Function Key menu selection.
50  CLEAR SCREEN
60  KEY LABELS ON
70  DUMP DEVICE IS 711
80  ON KEY 1 LABEL " TURBO  CHARGER" GOTO Turbo
90  ON KEY 2 LABEL "COMPRESSLAB" GOTO Compressor
100 ON KEY 3 LABEL "DESIGN" GOTO Design
110 ON KEY 4 LABEL "MULTI  PROGRAM" GOTO Hp6944a
120 ON KEY 5 LABEL "WORK  DIR " GOTO Work
130 ON KEY 6 LABEL "BACKUP" GOTO Backup
140 ON KEY 7 LABEL "PROGRAM LISTINGS" GOTO Directory
150 ON KEY 8 LABEL "EXIT  MENU" GOTO Exit
160 !
170 PRINT "HP9000 Series 300 Computer Data Acquisition System"
180 PRINT
190 PRINT "Item:                               Select Function Key"
200 PRINT
210 PRINT "  Turbocharger Lab (*)                      F1"
220 PRINT "  Transonic Compressor Lab (*)                 F2"
230 PRINT "  Turbine Design Programs (*)                 F3"
240 PRINT "  Multi-Programmer Opertion (HP6944A)          F4"
250 PRINT "  Work directory (*)                          F5"
260 PRINT "  Backup Files                               F6"
270 PRINT "  HP9000 Program Listing and Information      F7"
280 PRINT "  Exit Menu                                  F8"
290 PRINT
300 PRINT "Note: Binaries required for HP14753A CAT program are loaded"
310 PRINT "      to operate the HP6944A Multi-programmer."
320 PRINT "      Additional binaries are loaded with selection (*)."

```

Figure D2 TPL Program: AUTOST



```
660  LOAD BIN "/WORKSTATIONS/BIN5.1/TRANS"  
670  LOAD BIN "/WORKSTATIONS/BIN5.1/XREF"  
680  LOAD BIN "/WORKSTATIONS/BIN5.1/SERIAL"  
690  LOAD BIN "/WORKSTATIONS/BIN5.1/COMPLEX"  
700  RETURN  
710 Exit: CLEAR SCREEN  
720  END
```

Figure D2 (cont) TPL Program: AUTOST

```

10 ! FILE NAME: "TURBO1"
20 ! DISK LABEL: "/TURBINE"
30 ! DESCRIPTION:
40 ! THIS PROG RECORDS AND REDUCES
50 ! RAW DATA FOR THE T-18A40 TURBO-CHARGER
60 ! AS SET UP IN APRIL/MAY 1980 (RESET AUG 1991)
70 ! CHAN & PORT DESIGNATIONS ARE UNIQUE
80 !
90 ! VARIABLES FOR S/V SECTION
100 ! V=DESIRED S/V
110 ! P=PRESENT S/V PORT
120 ! VARIABLES FOR TEMP SECTION
130 ! SS=SCANNER LISTEN CODE
140 ! S=SCANNER #
150 ! C=CHANNEL
160 ! V=DVM READING
170 ! AUTHOR: TERRY EARGLE
180 ! DATE: JUL 79 (MOD MAY 80 BY M.J. KAISER)
190 ! MODIFIED BY MIKE JEDWAB 1987
200 ! MODIFIED BY KELLYHARRIS/ALAN MCGUIRE 1984
210 ! MODIFIED BY RICK WENDLAND AUG 1991
220 !
230 ! PROMPTS ADDED> ATMOSPHERIC PRESS.
231 ! RAW AND REDUCED DATA FILES USE DATE_RUN# CONTEXT IN THEIR NAME.
240 ! REDUCTION CHANGED TO USE A MEASURED STATIC PRESS FOR TURBINE
250 ! PRESSURE RATIO, I.E. INPUT STAGNATION PRESS, OUTPUT STATIC PRESS.
260 !
270 ! SCANIVALVE #1 SET TO ADVANCE ONLY!!!!!!!!!!
280 CLEAR SCREEN
290 PRINTER IS CRT
300 DISP "PLEASE WAIT WHILE RESETTING SCANIVALVE"
310 V=1
320 A=1
330 GOSUB Read
340 PRINT "DATA RUN FOR A TURBO-CHARGER"
350 PRINT
360 DIM X(20),Y(6),Q(8),M(23),T(19),Z(20),AS(14),BS(14)
370 E1=1 !Sets first record #-1
380 INPUT "STORING DATA ? (YES=1 NO=0)",G1
390 INPUT "ENTER MONTH, DAY, YEAR",X(3),X(5),X(7)
400 PRINT USING "K,DD,""/"/"DD,""/"/"DD";"DATE OF RUN: ",X(3),X(5),X(7)
410 INPUT "ENTER RUN #:",X(9)
420 IF G1=0 THEN 510
430 AS="RAW_"&VALS(X(7))&VALS(X(3))&VALS(X(5))&"_"&VALS(X(9))
440 BS="RED_"&VALS(X(7))&VALS(X(3))&VALS(X(5))&"_"&VALS(X(9))
450 CREATE ASCII AS&"",700,0,1",10 !Creates raw data file
460 CREATE ASCII BS&"",700,0,1",10 !Creates reduced data file
470 ASSIGN @Path1 TO AS&"",700,0,1"
480 ASSIGN @Path2 TO BS&"",700,0,1"
490 PRINT "RAW DATA FILE NAME: ";AS
500 PRINT "REDUCED DATA FILE NAME: ";BS
510 X(11)=1 !Sets first datat point #-1
520 GOTO 600
530 GOSUB Save
540 FOR I=2 TO 20 STEP 2 !Reset X(*) for pressures to zero
550 X(I)=0
560 NEXT I
570 FOR I=1 TO 5 !Reset Y(*) for temp & RPM to zero
580 Y(I)=0
590 NEXT I
600 PRINT USING "/,K,2D,4X,K,2D";"RUN #",X(9),"DATA PT #",X(11)
610 GOSUB 1130
620 !***** RECORD PRESSURES *****
630 OUTPUT 722;"F1R1MOZ16STG1STIT3"!Sets-up HP3456A DVM
640 V=1 !Scanivalve #1 designated

```

Figure D3 TPL Program: TURBO1



```

1300 T(C)=V                                !Storing temperatures in T(*)
1310 NEXT C
1320 FOR C=25 TO 26                        !Collecting temp (chls 25-26)
1330 OUTPUT 708;"C"
1340 OUTPUT 708 USING "DDD";C              !Scanner #2
1350 TRIGGER 722                           !Trigger DVM
1360 ENTER 722;V
1370 T(C-7)=V                              !Storing temperatures in T(18),T(19)
1380 NEXT C
1390 OUTPUT 708;"C"
1400 CLEAR 722
1410 T(6)=T(3)
1420 T(7)=T(5)
1430 T(3)=T(2)+T(18)
1440 T(5)=T(4)+T(19)
1450 FOR C=1 TO 5
1460 Y(C)=FNT(T(C)*1000)+460               !Converts temp to deg Rankine
1470 PRINT USING "2X,DDD,8X,6D.D";C,Y(C)
1480 NEXT C
1510 RETURN
1520 !***** SUBROUTINE FOR DATA REDUCTION *****
1530 !   TURBINE STATIC OUTLET PRESSURE WAS CHANGED FROM
1540 !   ATMOSPHERIC TO A VALVE MEASURED IN THE TURBINE OUTLET FLOW
1550 !
1560 !   VARIABLES FOR THIS SECTION
1570 !   M IS STORAGE ARRAY
1580 !   Q=MATRIX OF PRESS(IN. OF HG)
1590 !   M(1)=TURBINE HEAD(DELTA P ORIFICE)
1600 !   M(2)=COMPRESSOR HEAD(DELTA P COMPRESSOR)
1610 !   Y1=ORIFICE EXPANSION FACTOR(TURBINE)
1620 !   Y2=ORIFICE EXPANSION FACTOR(COMPRESSOR)
1630 !   K1=DISCHARGE COEF FOR FEED ORIFICE (TURB)
1640 !   K2=DISCHARGE COEF FOR FEED ORIFICE (COMP)
1650 !   C9=C SUB P FOR AIR= 0.24
1660 !   C8=CONV FACTOR BTU->HP
1670 !   C7=(GAMMA-1/GAMMA) WITH GAMMA=1.4
1680 !   Z1=ORIFACE FACTOR (TURB)
1690 !   Z2=ORIFACE FACTOR (COMPRESSOR)
1700 !   A3=ALPHA FACTOR (THERMAL) IN FLOW EQN (TURB)
1710 !   A4=ALPHA FACTOR (THERMAL) IN FLOW EQN (COMP)
1720 !   K3=FACTOR IN FLOW EQN (TURB)
1730 !   K4=FACTOR IN FLOW EQN (COMP)
1740 !   F1=FIRST ITERATION OF FLOW RATE (TURBINE)
1750 !   F2=FIRST ITERATION OF FLOW RATE (COMPRESSOR)
1760 !   M(3)=TURB FLOW RATE
1770 !   M(4)=COMP FLOW RATE
1780 !   M(5)=TURB HP
1790 !   M(6)=COMP HP
1800 !   M(7)=TURB PRESS RATIO (IN/OUT)
1810 !   M(8)=COMP PRESS RATIO (IN/OUT)
1820 !   M(9)=TURB EFFICIENCY (TOTAL-STATIC)
1830 !   M(10)=COMPRESSOR EFFICIENCY (TOTAL-TOTAL) MJ
1840 !   T0=REF TEMP (518.7 DEG R)
1850 !   M(11)=SQRT OF THETA (TURB) (T(IN)/T(REF))0.5
1860 !   M(12)=SQRT OF THETA (COMP)
1870 !   D0=REF PRESS (29.92 IN. HG)
1880 !   M(13)=REF PRESS RATIO (TURB IN/REF)
1890 !   M(14)=REF PRESS RATIO (COMP IN/REF)
1900 !   M(15)=REF TURB FLOW RATE
1910 !   M(16)=REF COMP FLOW RATE
1920 !   M(17)=REF TURB RPM
1930 !   M(18)=REF COMP RPM
1940 !   M(19)=REF TURB HP
1950 !   M(20)=REF COMP HP
1960 !   M(21)=DELTA TEMP(TURB)

```

Figure D3 (cont) TPL Program: TURBO1

```

1970 !      M(22)=DELTA TEMP(COMP)
1980 !      M(23)=HEAD COEFFICIENT
1990 MAI Q= (0)
2000 FOR I=6 TO 20 STEP 2
2010 Q(I/2-2)=((X(I)-X(2))*0.07355)+X(1)
2020 NEXT I
2030 M(1)=X(6)-X(8)
2040 M(2)=X(14)-X(16)
2050 Y1=1-.026*M(1)/Q(1)
2060 Y2=1-.02581*M(2)/Q(5)
2070 K1=1.4405
2080 K2=.63094
2090 C9=.24
2100 C8=1.414836364
2110 C7=.2857142857
2120 Z1=1.9+C9*(((Y(1)-460)/100)-1)
2130 Z2=1.9+C9*(((Y(4)-460)/100)-1)
2140 A3=1+.002044*(((Y(1)-528)/100)
2150 A4=1+.002044*(((Y(4)-528)/100)
2160 K3=.00327673
2170 K4=.0015472
2180 F1=K1*A3*Y1*SQR(ABS(Q(1)*M(1)/Y(1)))
2190 F2=K2*A4*Y2*SQR(ABS(Q(5)*M(2)/Y(4)))
2200 M(3)=F1/2*(1+SQR(ABS(1+4*K3*Z1/F1)))
2210 M(4)=F2/2*(1+SQR(ABS(1+4*K4*Z2/F2)))
2220 M(21)=Y(2)-Y(3)
2230 M(22)=Y(5)-Y(4)
2240 M(5)=M(3)*C8*M(21)*C8
2250 M(6)=M(4)*C9*M(22)*C8
2260 M(7)=Q(3)/Q(4)
2270 M(8)=Q(8)/Q(7)
2280 M(9)=(M(21)/Y(2))*((1/(1-(Q(4)/Q(3))^C7)))*100
2290 M(10)=Y(4)/M(22)*((M(8)^C7)-1)*100
2300 T0=518.7
2310 M(11)=SQR(Y(2)/T0)
2320 M(12)=SQR(Y(4)/T0)
2330 D0=29.92
2340 M(13)=Q(3)/D0
2350 M(14)=Q(7)/D0
2360 M(15)=M(3)*M(11)/M(13)
2370 M(16)=M(4)*M(12)/M(14)
2380 M(17)=Y(6)/M(11)
2390 M(18)=Y(8)/M(12)
2400 M(19)=M(5)/(M(13)*M(11))
2410 M(20)=M(6)/(M(14)*M(12))
2420 M(23)=12872868*Y(2)/Y(6)^2*(1-(Q(4)/Q(3))^C7)
2430 PRINT
2440 PRINT
2450 PRINT "REDUCED DATA:"
2460 PRINT
2470 PRINT "HEAD COEFFICIENT=";M(23)
2480 PRINT USING "/,8X,K";"HP      FLOW      DELTA      PRESS      EFF      FLOW      RPM      HP"
2490 PRINT USING "17X,K";"RATE      TEMP      RATIO      (REF)      (REF)      (REF)"
2500 !PRINT "XXXX XXXXX.X XXXXXX.XXX XXXXXX.X XXXXXX.XXX XXXXXX.X XXXXXX.XXX XXXXXX.X"
2510 PRINT USING "/,K,X,5D,D,X,6D,3D,X,6D,D,X,6D,3D,X,6D,D,X,6D,3D,X,6D,X,5D,D";"TURB",M(5),M(3)
2520 PRINT USING "/,K,X,5D,D,X,6D,3D,X,6D,D,X,6D,3D,X,6D,D,X,6D,3D,X,6D,X,5D,D";"COMP",M(6),M(4)
2530 !
2540 RETURN
2550 !**** SUBROUTINE TO SAVE DATA POINT ON HARD DRIVE :,700,0,1 *****
2560 Save: OUTPUT @Path1;AS
2570 OUTPUT @Path1;E1
2580 OUTPUT @Path1;X(*),Y(*),I(*)
2590 OUTPUT @Path2;BS
2600 OUTPUT @Path2;E1
2610 OUTPUT @Path2;M(*)

```

Figure D3 (cont) TPL Program: TURBO1

```

2620 RETURN
2630 REM**** END OF SUBROUTINES ****
2640 !
2650 LOAD "TURBO_LAB",10
2660 END
2670 !
2680 REM**** FUNCTION FOR TEMPERATURE COMPUTATION ****
2690 DEF FNT(V)
2700 S1=32.144+35.77*V-.4518*V^2
2710 S2=33.252+34.86*V-.1855*V^2
2720 IF S1<100 THEN 2740
2730 S1=S2
2740 RETURN S1
2750 FNEND
2760 REM**** END OF USER DEFINED FUNCTIONS ****

```

Figure D3 (cont) TPL Program: TURBO1

```

10 ! PROGRAM: TURBO2 (OLD TURBO3)
20 ! MODIFIED BY: R. SHREEVE 10/8/86
30 ! R. WENDLAND, LCDR, USN, 9/17/91
40 CLEAR SCREEN
50 DIM X(20),Y(6),I(19),IS(12),OS(12),US(14)
60 INTEGER E1
70 PRINTER IS CRT
80 INPUT "ENTER RAW DATA FILE NAME: ",US
90 INPUT "ENTER DATA POINT RECORD NUMBERS (LOW, HIGH): ",A,B
100 INPUT "DO YOU WANT TO DISPLAY RESULTS TO SCREEN OR PRINTER (SCREEN=0 PRINTER=1)? ",R
110 IF R=0 THEN 130
120 PRINTER IS 711
130 ASSIGN @Path TO US$:700,0,1"
140 ON END @Path GOTO Continue1
150 GOSUB Read
160 IS=" INLET"
170 OS=" OUTLET"
180 PRINT "-----"
190 PRINT TAB(23);"CUMMINS TURBOCHARGER MEASURED DATA"
200 PRINT "-----"
210 PRINT USING "16X,K,DD,19X,K,DD,K,DD,K,DD";"RUN #",X(9),"DATE: ",X(3),"/",X(5),"/",X(7)
220 PRINT "-----"
230 PRINT USING "/,/,27X,K";"PRESSURES (IN. H2O GAUGE)"
240 PRINT USING "20X,K,5X,K";" | ORIFICE | TURBINE | NOZZLE",", | COMPRESSOR"
250 PRINT "POINT TARE CALIB. |";TAB(36);"|";TAB(51);"|";TAB(66);"| "
260 PRINT USING "K,14X,K,K,K,K,K,K,K,K";" NO. ",IS,OS,IS,OS,IS,OS,IS,OS
270 PRINT USING "10D,6D,8D,7D,8D,7D,8D,7D,8D,8D";1,2,3,4,5,6,7,8,9,10
280 PRINT "-----"
290 Print1: IF E1<A THEN Loop1
300 PRINT USING "3D,6D,D,5D,D,6D,D,5D,D,6D,D,5D,D,6D,D,5D,D";X(11),X(2),X(4),X(6),X(8)
310 IF E1=B THEN Continue1
320 Loop1:GOSUB Read
330 GOTO Print1
340 Continue1: PRINT "-----"
350 ASSIGN @Path TO US$:700,0,1"
360 ON END @Path GOTO Continue2
370 E1=0
380 GOSUB Read
390 IS=" INLET"
400 OS=" OUTLET"
410 PRINT USING "/,/,47X,K";"TEMPERATURES (DEG R)"
420 PRINT USING "28X,K";" | "
430 PRINT USING "K,5X,K,4X,K,10X,K,6X,K,7X,K,4X,K";"POINT", "RPM", "ATM. PRESS |", "|", "TURBINE", "
440 PRINT USING "K,15X,K,K,K,K,K,K";" NO. ";"(IN. HG) ORIFICE", IS,OS,IS,OS
450 PRINT USING "23X,11D,11D,10D,11D,10D";1,2,3,4,5
460 PRINT "-----"
470 Print2: IF E1<A THEN Loop2
480 PRINT USING "3D,11D,8D,DD,9D,D,8D,D,9D,D,8D,D";X(11),Y(6),X(1),Y(1),Y(2),Y(3),Y(4),Y(5)
490 IF E1=B THEN Continue2
500 Loop2:GOSUB Read
510 GOTO Print2
520 Continue2: PRINT "-----"
530 PRINT TAB(21);"NOTE: CHANNEL AND PORT NUMBERS INDICATED"
540 PRINT "-----"
550 GOTO Hold
560 Read: ENTER @Path;AS
570 ENTER @Path;E1
580 ENTER @Path;X(*)
590 ENTER @Path;Y(*)
600 ENTER @Path;I(*)
610 RETURN
620 Hold:DISP "F2 TO CONTINUE"
630 PAUSE
640 PRINTER IS CRT
650 LOAD "TURBO_LAB",10
660 END

```

Figure D4 TPL Program: TURBO2

```

10 ! PROGRAM: TURBO3 (OLD TURBO4)
20 ! MODIFIED BY: R. SHREEVE 10/8/86
30 ! R. WENDLAND, LCDR, USN, 9/20/91
40 CLEAR SCREEN
50 DIM X(20),Y(6),I(19),M(23),US(14),VS(14)
60 INTEGER E1,E2
70 PRINTER IS CRT
80 INPUT "ENTER RAW DATA FILE NAME: ",US
90 INPUT "ENTER REDUCED DATA FILE NAME: ",VS
100 INPUT "ENTER DATA POINT RECORD NUMBERS (LOW, HIGH): ",A,B
110 INPUT "DO YOU WANT TO DISPLAY RESULTS TO SCREEN OR PRINTER (SCREEN=0 PRINTER=1)?",R
120 IF R=0 THEN 140
130 PRINTER IS 711
140 ASSIGN @Path1 TO US&":,700,0,1"
150 ASSIGN @Path2 TO VS&":,700,0,1"
160 ON END @Path1 GOTO Continue1
170 ON END @Path2 GOTO Continue1
180 GOSUB Read
190 PRINT "-----"
200 PRINT TAB(23);"CUMMINS TURBOCHARGER CALCULATED DATA"
210 PRINT "-----"
220 PRINT USING "16X,K,DD,19X,K,DD,K,DD,K,DD";"RUN #",X(9),"DATE: ",X(3),"/",X(5),"/",X(7)
230 PRINT "-----"
240 PRINT USING "/,/,32X,K";"TURBINE DATA"
250 PRINT USING "9X,K";"POINT PRESS REF REF HP REF HEAD EFF"
260 PRINT USING "10X,K";"NO. RATIO RPM FLOW HP COEFF (Z)"
270 PRINT USING "16X,K,9X,K";"(P6/P5)", "(LBM/SEC)"
280 PRINT USING "10X,K";" M(7) M(17) M(15) M(5) M(19) M(23) M(9)"
290 PRINT "-----"
300 Print1: IF E1<A THEN Loop1
310 PRINT USING "9X,3D,6D,2D,9D,5D,3D,6D,2D,5D,2D,3D,3D,5D,D";X(11),M(7),M(17),M(15),M(5),M(19),
320 IF E1=B THEN Continue1
330 Loop1:GOSUB Read
340 GOTO Print1
350 Continue1: PRINT "-----"
360 ASSIGN @Path1 TO US&":,700,0,1"
370 ASSIGN @Path2 TO VS&":,700,0,1"
380 ON END @Path1 GOTO Continue2
390 ON END @Path2 GOTO Continue2
400 E1=0
410 GOSUB Read
420 PRINT USING "/,/,30X,K";"COMPRESSOR DATA"
430 PRINT USING "9X,K";"POINT PRESS RPM REF REF HP REF EFF"
440 PRINT USING "10X,K";"NO. RATIO RPM FLOW HP (Z)"
450 PRINT USING "15X,K,16X,K";"(P10/P9)", "(LBM/SEC)"
460 PRINT USING "10X,K";" M(8) M(18) M(16) M(6) M(20) M(10)"
470 PRINT "-----"
480 Print2: IF E1<A THEN Loop2
490 PRINT USING "9X,3D,6D,2D,9D,8D,4D,3D,5D,2D,4D,2D,4D,D";X(11),M(8),Y(6),M(18),M(16),M(6),M(20)
500 IF E1=B THEN Continue2
510 Loop2:GOSUB Read
520 GOTO Print2
530 Continue2: PRINT "-----"
540 GOTO Hold
550 Read: ENTER @Path1;AS
560 ENTER @Path1;E1
570 ENTER @Path1;X(*)
580 ENTER @Path1;Y(*)
590 ENTER @Path1;I(*)
600 ENTER @Path2;BS
610 ENTER @Path2;E2
620 ENTER @Path2;M(*)
630 RETURN
640 Hold:DISP "F2 TO CONTINUE"
650 PAUSE

```

Figure D5 TPL Program: TURBO3



```
660  PRINTER IS CRT
670  LOAD "TURBO_LAB",10
680  END
```

Figure D5 (cont) TPL Program: TURBO3

```

10  !Program: TURBO4 Plots data from designated ASCII files to the CRT or Printer
20  !Developed: by R. Wendland, LCDR, USN, 22 Sept 1991
30  !
40  DIM Title$(50),X_label$(50),Y_label$(50),Red_file$(14),M(23),Data1(1:20,23),Data2(1:20,23)
50  CLEAR SCREEN
60  !EY LABELS OFF
70  PRINTER IS CRT
80  !
90  !----- Load working matrix Data: -----
100 Load_matrix: !
110  INPUT "Number of plots per graph (1 to 3):",Num_plots
120  FOR K=1 TO Num_plots
130    INPUT "Enter reduced data file name:",Red_file$
140    PRINT "Data file #";K;"": " ";Red_file$
150    ASSIGN @Path TO Red_file$&"":,700,0,1"
160    ON END @Path GOTO 410
170    I=1
180  Read:ENTER @Path;AS
190    ENTER @Path;E1
200    ENTER @Path;M(*)
210    SELECT K
220    CASE 1
230      FOR J=0 TO 23
240        Data1(I,J)=M(J)
250      NEXT J
260      D1=D1+1
270    CASE 2
280      FOR J=0 TO 23
290        Data2(I,J)=M(J)
300      NEXT J
310      D2=D2+1
320    CASE 3
330      FOR J=0 TO 23
340        Data3(I,J)=M(J)
350      NEXT J
360      D3=D3+1
370    END SELECT
380    I=I+1
390    GOTO Read
400    I=0
410  NEXT K
420  !
430  !----- Define graph parameters: -----
440  Graph_parameter: !
450  INPUT "Enter graph title:",Title$
460  PRINT "Graph title: ";Title$
470  INPUT "Enter X-axis label:",X_label$
480  PRINT "X-axis label: ";X_label$
490  INPUT "Enter Y-axis label:",Y_label$
500  PRINT "Y-axis label: ";Y_label$
510  INPUT "Enter X-axis and Y-axis M-values( M(x),M(y) ):",X,Y
520  FOR K=1 TO Num_plots
530    SELECT K
540    CASE 1
550      PRINT
560      PRINT "Data file #";K;"": " "
570      PRINT X_label$;TAB(25);Y_label$
580      FOR I=1 TO D1
590        PRINT Data1(I,X),Data1(I,Y)
600      NEXT I
610    CASE 2
620      PRINT
630      PRINT "Data file #";K;"": " "
640      PRINT X_label$;TAB(25);Y_label$
650      FOR I=1 TO D2

```

Figure D6 TPL Program: TURBO4

```

660     PRINT Data2(I,X),Data2(I,Y)
670     NEXT I
680     CASE 3
690     PRINT
700     PRINT "Data file #";K;":"
710     PRINT X_label$;TAB(25);Y_label$
720     FOR I=1 TO D3
730     PRINT Data3(I,X),Data3(I,Y)
740     NEXT I
750     END SELECT
760     NEXT K
770     INPUT "Enter Xmin, Xmax, Ymin, Ymax:",Xo,Xf,Yo,Yf
780     !
790     !---- Graph data -----
800 Graph_data: !
810     CLEAR SCREEN
820     GINIT                      !Initialize graph routine
830     Xso=Xo                      ! Initialize all scaling variables
840     Xsf=Xf
850     Yso=Yo
860     Ysf=Yf
870     Xs_range=Xsf-Xso
880     Ys_range=Ysf-Yso
890     Xscale=1
900     Yscale=1
910     IF Xs_range<1000 THEN      ! Scale up graph variables for minimum of
920     Xs_range=Xs_range*10      ! of 1000 units of resolution across x-axis
930     Xscale=Xscale*10
940     GOTO 910
950     END IF
960     IF Ys_range<1000 THEN      ! Scale up graph variables for minimum of
970     Ys_range=Ys_range*10      ! of 1000 units of resolution across y-axis
980     Yscale=Yscale*10
990     GOTO 960
1000    END IF
1010    Xso=Xo*Xscale              ! Finalize all scaling variables
1020    Xsf=Xf*Xscale
1030    Yso=Yo*Yscale
1040    Ysf=Yf*Yscale
1050    Xs_range=Xsf-Xso           !Length of X-axis
1060    Ys_range=Ysf-Yso           !Length of Y-axis
1070    LORG 5                     !Character ref pt:top center
1080    MOVE 100*RATIO/2,100      !Move cursor to screen loc for labels
1090    LABEL Title$              !Plot title
1100    CSIZE 3.5                 !Sizes labeling
1110    MOVE 100*RATIO/2,0        !Move cursor to bottom center screen
1120    LORG 4                     !Character ref pt:bottom center
1130    LABEL X_label$           !X-axis label
1140    DEG                       !Desig degrees for LDIR
1150    LDIR 90                   !Sets Y-axis label on end
1160    LORG 6
1170    MOVE 0,50
1180    LABEL Y_label$           !Y-axis label
1190    LDIR 0                     !Reset label to horizontal orientation.
1200    LORG 2                     !Chr ref pt:left center
1210    VIEWPORT 10,90*RATIO,10,90 !Sets graph screen size
1220    FRAME                     !Box around VIEWPORT
1230    WINDOW Xso,Xsf,Yso,Ysf    !Set axis lengths in VIEWPORT
1240    AXES Xs_range/10,Ys_range/10,Xso,Yso !Axes intersect at lower left
1250    AXES Xs_range/10,Ys_range/10,Xsf,Ysf !Axes intersect at upper right
1260    CLIP OFF                  !So labels can print outside VIEWPORT
1270    CSIZE 3.0,.4              !Axes label size
1280    LORG 6                     !Number X-axis
1290    FOR I=Xso TO Xsf STEP Xs_range/10
1300    MOVE I,Yso-.01*Ys_range

```

Figure D6 (cont) TPL Program: TURBO4

```

1310 LABEL USING "#,K";I/Xscale
1320 NEXT I
1330 LORG 8 !Number Y-axis
1340 FOR I=Yso TO Ysf STEP Ys_range/10
1350 MOVE Xso-.01*Xs_range,I
1360 LABEL USING "#,K";I/Yscale
1370 NEXT I
1380 FOR K=1 TO Num_plots
1390 SELECT K
1400 CASE 1
1410 FOR I=1 TO D1
1420 PLOT Data1(I,X)*Xscale,Data1(I,Y)*Yscale,-2 ! Plots Data1 as squares
1430 FDIR 45
1440 POLYGON .01*Xs_range,4
1450 NEXT I
1460 CASE 2
1470 FOR I=1 TO D2
1480 PLOT Data2(I,X)*Xscale,Data2(I,Y)*Yscale,-2 ! Plots Data2 as diamonds
1490 FDIR 0
1500 POLYGON .01*Xs_range,4
1510 NEXT I
1520 CASE 3
1530 FOR I=1 TO D3
1540 PLOT Data3(I,X)*Xscale,Data3(I,Y)*Yscale,-2 ! Plots Data3 as triangles
1550 FDIR 90
1560 POLYGON .01*Xs_range,3
1570 NEXT I
1580 END SELECT
1590 NEXT K
1600 IF Plot=0 THEN Hard_copy
1610 DUMP GRAPHICS #711
1620 GOTO Another_plot
1630 !
1640 !---- Hard copy plots of graphs -----
1650 Hard_copy: !
1660 INPUT "Plot graph: (No=0 Printer=1 Plotter=2)",Plot
1670 IF Plot=0 THEN Another_plot
1680 IF Plot=1 THEN Graph_data
1690 !---- Plotter rout' -----
1700 Plotter: !
1710 PRINTER IS 712
1720 Xso=Xo ! Initialize all scaling variables
1730 Xsf=Xf
1740 Yso=Yo
1750 Ysf=Yf
1760 Xs_range=Xsf-Xso
1770 Ys_range=Ysf-Yso
1780 Xscale=1
1790 Yscale=1
1800 IF Xs_range<1000 THEN ! Scale up graph variables for minimum of
1810 Xs_range=Xs_range*10 ! of 1000 units of resolution across x-axis
1820 Xscale=Xscale*10
1830 GOTO 1800
1840 END IF
1850 IF Ys_range<1000 THEN ! Scale up graph variables for minimum of
1860 Ys_range=Ys_range*10 ! of 1000 units of resolution across y-axis
1870 Yscale=Yscale*10
1880 GOTO 1850
1890 END IF
1900 Xsf=INT(Xf*Xscale)
1910 IF Xsf>16383 THEN ! Readjust graph variables to ensure x-axis
1920 Xsf=Xsf/10 ! Xsf does not exceed 16383 units
1930 Xscale=Xscale/10
1940 GOTO 1910
1950 END IF

```

Figure D6 TPL Program: TURBO4

```

1960 Ysf=INT(Yf*Yscale)
1970 IF Ysf>16383 THEN          ! Readjust graph variables to ensure y-axis
1980   Ysf=Ysf/10              ! Xsf does not exceed 16383 units
1990   Yscale=Yscale/10
2000   GOTO 1970
2010 END IF
2020 Xso=INT(Xo*Xscale)          ! Finalize all scaling variables
2030 Xsf=INT(Xf*Xscale)
2040 Yso=INT(Yo*Yscale)
2050 Ysf=INT(Yf*Yscale)
2060 PRINT "IN;IP1000,1000,9500,7000;"      ! Set paper size
2070 PRINT "SC";Xso,"";Xsf,"";Yso,"";Ysf;"  ! Set X & Y axes lengths
2080 PRINT "PA";Xso,"";Yso,"";SP1;PD;"
2090 FOR Xp=Xso TO Xsf STEP (Xsf-Xso)/10    ! Print X-axis
2100   PRINT "PA";Xp,"";Yso,"";XT;PU;"
2110   PRINT "CP-2.4,-1.3;LB";Xp/Xscale;CHRS(3)
2120   PRINT "PA";Xp,"";Yso,"";PD;"
2130 NEXT Xp
2140 PRINT "PU;PA";Xso+INT(.4*(Xsf-Xso));",",Yso-INT(.078*(Ysf-Yso));",LB";X_label$;CHRS(3)
2150 PRINT "PU;PA";Xso,"";Ysf,"";PD;"
2160 FOR Yp=Yso TO Ysf STEP (Ysf-Yso)/10    ! Print Y-axis
2170   PRINT "PA";Xp,"";Yp,"";YT;PU;"
2180 NEXT Yp
2190 PRINT "PU;PA";Xso,"";Yso,"";PD;"
2200 FOR Yp=Yso TO Ysf STEP (Ysf-Yso)/10    ! Print Y-axis
2210   PRINT "PA";Xso,"";Yp,"";YT;PU;"
2220   PRINT "CP-6.4,-.3;LB";Yp/Yscale;CHRS(3)
2230   PRINT "PA";Xso,"";Yp,"";PD;"
2240 NEXT Yp
2250 PRINT "PU;PA";Xso-INT(.09*(Xsf-Xso));",",Yso+INT(.375*(Ysf-Yso));",DI0,1;LB";Y_label$;CHRS(3)
2260 PRINT "PA";Xsf,"";Yso,"";PD;"
2270 FOR Yp=Yso TO Ysf STEP (Ysf-Yso)/10
2280   PRINT "PA";Xsf,"";Yp,"";YT;"
2290 NEXT Yp
2300 PRINT "PU;PA";Xso+INT(.4*(Xsf-Xso));",",INT(.078*(Ysf-Yso))+Ysf,"";DI1,0;LB";Title$;CHRS(3)
2310 FOR K=1 TO Num_plots          ! Plot data points
2320   SELECT K
2330   CASE 1
2340     FOR I=1 TO D1
2350       PRINT "PA";INT(Data1(I,X)*Xscale);",",INT(Data1(I,Y)*Yscale);",;"
2360       PRINT "UC-3,-4,99,0,8,6,0,0,-8,-6,0,-99;" ! Plots squares for graph #1
2370     NEXT I
2380   CASE 2
2390     FOR I=1 TO D2
2400       PRINT "PA";INT(Data2(I,X)*Xscale);",",INT(Data2(I,Y)*Yscale);",;"
2410       PRINT "UC0,-4,99,-3,4,3,4,3,-4,-3,-4,-99;" ! Plots diamonds for graph #2
2420     NEXT I
2430   CASE 3
2440     FOR I=1 TO D3
2450       PRINT "PA";INT(Data3(I,X)*Xscale);",",INT(Data3(I,Y)*Yscale);",;"
2460       PRINT "UC-3,-4,99,3,8,3,-8,-6,0,-99;" ! Plots triangles for graph #3
2470     NEXT I
2480   END SELECT
2490 NEXT K
2500 PRINT "PU;PA";Xsf,"";Ysf,"";"
2510 PRINTER IS CRT
2520 !---- Additional plots/End of routines -----
2530 Another_plot: !
2540 INPUT "Plot another graph? (Yes=1 No=0)",Replot
2550 Plot=0
2560 CLEAR SCREEN
2570 IF Replot=1 THEN Graph_parameter
2580 CLEAR SCREEN
2590 KEY LABELS ON
2600 LOAD "TURBO_LAB",10

```

Figure D6 TPL Program: TURBO4

```

10  !Program: SCAN_TEMP
20  !Description: Reads thermo-couple emf from channels 0-5, converts to
30  !             degrees F, and prints to CRT.
40  !Devices: HP3495A(708), HP3456A(722)
50  !
60  CLEAR SCREEN
70  DUMP DEVICE IS 711
80  DIM Y(5,1:2),T(5)
90  INTEGER Run
100 DIM Channel$(5){20}
110 Channel$(0)="Atmosphere"
120 Channel$(1)="Supply Orifice"
130 Channel$(2)="Turbine Inlet"
140 Channel$(3)="Turbine Outlet"
150 Channel$(4)="Compressor Inlet"
160 Channel$(5)="Compressor Outlet"
170 !
180 PRINT "Turbocharger Lab Temperature Readings."
190 Scan: !-----
200 Run=Run+1
210 PRINT
220 PRINT "Run number: ";Run
230 PRINT USING "K,11X,K,3X,K";"Location","Channel #"," Temperature (F)"
240 PRINT
250 OUTPUT 722;"T3"
260 FOR C=0 TO 5 'Reading temperature channels 0-5
270     OUTPUT 708 USING "DDD";C
280     TRIGGER 722
290     ENTER 722;T(C)
300     Y(C,1)=C
310     Y(C,2)=FNT(T(C)*1000) 'User defined function applied
320     IF Y(C,2)<ABS(.1) THEN
330         Y(C,2)=0
340     END IF
350     PRINT USING "20A,2X,DD,11X,5D.D";Channel$(C),Y(C,1),Y(C,2)
360 NEXT C
370 CLEAR 722
380 INPUT "Enter: 1=Rescan 0=Quit",Rescan
390 IF Rescan=1 THEN Scan
400 LOAD "TURBO_MENU",10
410 END!-----
420 !User defined function to convert voltage readings from temperature probes
430 !to temperature values in degrees F.
440 DEF FNT(V)
450     S1=32.144+35.77*V-.4518*V^2
460     S2=33.252+34.86*V-.1855*V^2
470     IF S1<100 THEN 490
480     S1=S2
490     RETURN S1
500 FNEND

```

Figure D7 TPL Program: SCAN\_TEMP

```

10  !Program: TURBO MENU
20  !Description: Program provides Function Key menu for program selection.
30  CLEAR SCREEN
40  ON KEY 1 LABEL "TURBO1" GOTO Turbo1
50  ON KEY 2 LABEL "TURBO2" GOTO Turbo2
60  ON KEY 3 LABEL "TURBO3" GOTO Turbo3
70  ON KEY 4 LABEL "TURBO4" GOTO Turbo4
80  ON KEY 5 LABEL "SCAN  TEMP " GOTO Temp
90  ON KEY 6 LABEL " " GOTO Hold
100 ON KEY 7 LABEL "MAIN  MENU" GOTO Main
110 ON KEY 8 LABEL "EXIT  MENU" GOTO Exit
120 !
130 PRINT "Turbocharger Data Acquisition Lab"
140 PRINT
150 PRINT "Item:                               Select Function Key"
160 PRINT
170 PRINT "  TURBO1:  Collect, reduce and          F1"
180 PRINT "             store RAW Data"
190 PRINT
200 PRINT "  TURBO2:  Tabulate RAW Data                F2"
210 PRINT
220 PRINT "  TURBO3:  Tabulate REDUCED Data             F3"
230 PRINT
240 PRINT "  TURBO4:  Plot REDUCED Data                 F4"
250 PRINT
260 PRINT "  SCAN_TEMP: Scan temperature probs          F5"
270 PRINT
280 PRINT "  Main Menu                                F7"
290 PRINT "  Exit Menu                                F8"
300 !
310 Hold:  !
320 GOTO Hold
330 Turbo1: !
340 LOAD "TURBO1",10
350 Turbo2: !
360 LOAD "TURBO2",10
370 Turbo3: !
380 LOAD "TURBO3",10
390 Turbo4: !
400 LOAD "TURBO4",10
410 Temp:  !
420 LOAD "SCAN_TEMP",10
430 Discrepancies: !
440 LOAD "DISCREP_DOC",10
450 Main:  !
460 MASS STORAGE IS "/WORKSTATIONS"
470 LOAD "AUTOST",10
480 Exit: CLEAR SCREEN
490 END

```

Figure D8 TPL Program: TURBO\_MENU

```

10  !Title:  A_4431T
20  !Author:  R.P. Shreeve (Rev. 12/3/89)
30  !Updated:  R.A. Wendland (12/12/91)
40  !Program:  Performance calculations for turbine for varying
50  !           Alpha1.
60  !
70  CLEAR SCREEN
80  DUMP DEVICE IS 711
90  KEY LABELS OFF
100 DIM A(7,15),B(7,15),C(7,15),R(15),S(15),Alpha1(15)
110 DEG                                     ! All angles in degrees
120 INPUT "Print results to CRT or Printer? (CRT=1, Printer=0): ",Crt
130 IF Crt=1 THEN 150
140 PRINTER IS 711
150 !----- Input data -----
160 R9=.08
170 P9=1
180 Q9=517.8
190 P0=2
200 P2=1
210 T0=560
220 U0=800
230 H1=14
240 ! A1=75                                ! Program modified for Alpha1 iteration
250 G1=1.4
260 G0=32.174
270 K9=.98
280 N0=35000
290 INPUT "Enter R*: ",R0
300 INPUT "Enter Alpha1 (deg): min, max, step size ==> ",L1,L2,L3
310 !----- Calculate needed quantities -----
320 V0=109.62*SQRT(T0)
330 X3=U0/V0
340 P4=P2/P0
350 R8=R9*(P0/P9)/(T0/Q9)
360 !----- Calculate performance -----
370 I=1
380 L4=0
390 FOR A1=L1 TO L2 STEP L3
400 GOSUB Non_dimension
410 T8=T9*T0
420 H0=(V0*V0/(2*G0))*T9/550
430 P1=P3*P0
440 T1=S1*T0
450 T2=S2*T0
460 V1=X1*V0
470 V2=X2*V0
480 W1=X5*V0
490 W2=X6*V0
500 W0=H1/H0
510 X9=X1*COS(A1)
520 A9=(W0*144/(R8*V0))/((X9*(1-X9^2)^(1/(1-G1)))^K9)
530 R7=(360*U0)/(PI*N0)
540 H9=A9/(2*PI*R7)
550 PRINT "R*=";R0;"RM=";R7;"H=";H9;"W0=";W0
560 !----- Store data in array -----
570 R(I)=R0
580 S(I)=R1
590 Alpha1(I)=A1
600 A(1,I)=N1
610 A(2,I)=N2
620 A(3,I)=H0
630 A(4,I)=T8
640 A(5,I)=P1
650 A(6,I)=T1

```

Figure D9 TPL Program: A\_4431T



```

660 A(7,I)=T2
670 B(1,I)=V1
680 B(2,I)=W1
690 B(3,I)=V2
700 B(4,I)=W2
710 B(5,I)=B1
720 B(6,I)=-A2
730 B(7,I)=-B2
740 C(1,I)=Z1
750 C(2,I)=Z2
760 C(3,I)=M3
770 C(4,I)=M4
780 C(5,I)=M5
790 C(6,I)=M6
800 C(7,I)=0
810 I=I+1
820 L4=L4+1
830 NEXT A1
840 !----- Print data -----
850 PRINT USING "/,K,5D.2D,K,5D.2D,K,6D,K";"PT0=",P0,"      P2=",P2," ATO.      TT0=",T0," DEG. R"
860 PRINT USING "/,K,6D,K,/" ;"WHEEL VEL.=",U0," FT/SEC."
870 FOR I=1 TO L4
880 PRINT USING "K,5D";"ALPHA1=",Alpha1(I)
890 NEXT I
900 PRINT USING "/,K,K,K,K,K,K,K,K,K,K";" ETA T-S"," ETA T-T"," HP/LB "," DELTW ","      P1 ","
910 FOR I=1 TO L4
920 PRINT USING "4D.3D,4D.3D,3D.4D,3D.4D,3D.4D,5D.2D,5D.2D,5D.2D,3D.4D";A(1,I),A(2,I),A(3,I),A(
930 NEXT I
940 PRINT USING "/,K,K,K,K,K,K,K,K,K,K";"      V1 ","      W1 ","      V2 ","      W2 ","      BETA1 ","
950 FOR I=1 TO L4
960 PRINT USING "6D.D,6D.D,6D.D,6D.D,6D.D,6D.D,6D.D,5D.2D,3D.4D";B(1,I),B(2,I),B(3,I),B(4,I),B(
970 NEXT I
980 PRINT USING "/,K,K,K,K,K,K,K,K,K,K";" ZETA S"," ZETA R"," M1CRIT"," M2CRIT"," MR1CRIT","
990 FOR I=1 TO L4
1000 PRINT USING "3D.4D,3D.4D,3D.4D,3D.4D,3D.4D,3D.4D,8X,5D.2D,3D.4D";C(1,I),C(2,I),C(3,I),C(4,I
1010 NEXT I
1020 GOTO 1410
1030 !----- Subroutine for non-dimension performance calculations -----
1040 Non_dimension: !
1050 G2=(G1-1)/G1
1060 G3=SQRT((G1+1)/(G1-1))
1070 T4=P4*G2
1080 T3=T4+R0*(1-T4)
1090 P3=T3^(1/G2)
1100 Y1=1-T3
1110 M1=(2/(G1-1))*(Y1/(1-Y1))
1120 Z1=.1*M1
1130 S1=T3+Z1*Y1
1140 X1=SQRT(1-S1)
1150 X4=X1*COS(A1)
1160 B1=ATN((X1*SIN(A1)-X3)/X4)
1170 X5=X4/COS(B1)
1180 T7=S1+X5^2
1190 T5=S1*(P4/P3)^G2
1200 Y6=T7-T5
1210 M2=(2/(G1-1))*Y6/T5
1220 Z2=.2*M2
1230 S2=T5+Z2*Y6
1240 X6=SQRT(T7-S2)
1250 B2=X4/X6
1260 B2=ATN(SQRT(1-B2^2)/B2)
1270 A2=ATN((X6*SIN(B2)-X3)/X4)
1280 X2=X4/COS(A2)
1290 S3=S2+X2^2
1300 T9=1-S3

```

Figure D9 (cont) TPL Program: A\_4431T

```

1310 N1=T9/(1-T4)
1320 P5=P4*(S3/S2)^(1/G2)
1330 T6=P5^G2
1340 N2=T9/(1-T6)
1350 R1=(S1-S2)/(1-S3)
1360 M3=X1*G3
1370 M4=X2*G3*SQRT(1/S3)
1380 M5=X5*G3*SQRT(1/T7)
1390 M6=X6*G3*SQRT(1/T7)
1400 RETURN
1410 DISP "Press F2 to exit, press F3 for another run"
1420 PRINTER IS CRT
1430 PAUSE
1440 LOAD "DESIGN_MENU",10
1450 END

```

Figure D9 (cont) TPL Program: A\_4431T .

```

10  !Title:  R_4431T
20  !Author:  R.P. Shreeve (Rev. 12/3/89)
30  !Updated:  R.A. Wendland (11/30/91)
40  !Program:  Performance calculations for turbine for varying
50  !           theoretical degree of reaction.
60  !
70  CLEAR SCREEN
80  DUMP DEVICE IS 711
90  KEY LABELS OFF
100 DIM A(7,15),B(7,15),C(7,15),R(15),S(15)
110 INPUT "Print results to CRT or Printer? (CRT=1, Printer=0): ",Crt
120 IF Crt=1 THEN 140
130 PRINTER IS 711
140 !----- Input data -----
150 R0=.08
160 P9=1
170 Q9=517.8
180 P0=2
190 P2=1
200 T0=560
210 U0=800
220 H1=14
230 A1=75
240 G1=1.4
250 G0=32.174
260 K9=.98
270 N0=35000
280 !----- Calculate needed quantities -----
290 V0=109.62*SQRT(T0)
300 X3=U0/V0
310 P4=P2/P0
320 R8=R9*(P0/P9)/(T0/Q9)
330 DEG
340 !----- Calculate performance -----
350 INPUT "Enter R*: min, max, step size",L1,L2,L3
360 I=1
370 L4=0
380 FOR R0=L1 TO L2 STEP L3
390 GOSUB Non_dimension
400 T8=T9*T0
410 H0=(V0*V0/(2*G0))*T9/550
420 P1=P3*P0
430 T1=S1*T0
440 T2=S2*T0
450 V1=X1*V0
460 V2=X2*V0
470 W1=X5*V0
480 W2=X6*V0
490 W0=H1/H0
500 X9=X1*COS(A1)
510 A9=(W0*144/(R8*V0))/(X9*(1-X9^2)^(1/(1-G1))*K9)
520 R7=(360*U0)/(PI*N0)
530 H9=A9/(2*PI*R7)
540 PRINT "R*=";R0;"RM=";R7;"H=";H9;"W0=";W0
550 !----- Store data in array -----
560 R(I)=R0
570 S(I)=R1
580 A(1,I)=N1
590 A(2,I)=N2
600 A(3,I)=H0
610 A(4,I)=T8
620 A(5,I)=P1
630 A(6,I)=T1
640 A(7,I)=T2
650 B(1,I)=V1

```

Figure D10 TPL Program: R\_4431T

```

660 B(2,I)=W1
670 B(3,I)=V2
680 B(4,I)=W2
690 B(5,I)=B1
700 B(6,I)=-A2
710 B(7,I)=-B2
720 C(1,I)=Z1
730 C(2,I)=Z2
740 C(3,I)=M3
750 C(4,I)=M4
760 C(5,I)=M5
770 C(6,I)=M6
780 C(7,I)=0
790 I=I+1
800 L4=L4+1
810 NEXT R0
820 !----- Print data -----
830 PRINT USING "//,/,/,/,K,5D.2D,K,5D.2D,K,6D,K";"PT0=",P0," P2=",P2," ATO. TT0=",T0,"
840 PRINT USING "//,K,6D,K,5D,K";"WHEEL VEL.=",U0," FT/SEC. ALPHA1=",A1," DEG."
850 PRINT USING "//,/,K,K,K,K,K,K,K,K,K";" ETA T-S"," ETA T-T"," HP/LB "," DELTW "," P1 ","
860 FOR I=1 TO L4
870 PRINT USING "4D.3D,4D.3D,3D.4D,3D.4D,3D.4D,5D.2D,5D.2D,5D.2D,3D.4D";A(1,I),A(2,I),A(3,I),A(4,
880 NEXT I
890 PRINT USING "//,/,K,K,K,K,K,K,K,K,K";" V1 "," W1 "," V2 "," W2 "," BETA1 ",
900 FOR I=1 TO L4
910 PRINT USING "6D.D,6D.D,6D.D,6D.D,6D.D,6D.D,6D.D,5D.2D,3D.4D";B(1,I),B(2,I),B(3,I),B(4,I),B(5
920 NEXT I
930 PRINT USING "//,/,K,K,K,K,K,K,K,K,K";" ZETA S"," ZETA R"," M1CRIT"," M2CRIT"," MR1CRIT","
940 FOR I=1 TO L4
950 PRINT USING "3D.4D,3D.4D,3D.4D,3D.4D,3D.4D,3D.4D,3D.4D,8X,5D.2D,3D.4D";C(1,I),C(2,I),C(3,I),C(4,I)
960 NEXT I
970 GOTO 1360
980 !----- Subroutine for non-dimension performance calculations -----
990 Non dimension: !
1000 G2=(G1-1)/G1
1010 G3=SQRT((G1+1)/(G1-1))
1020 T4=P4^G2
1030 T3=T4+R0*(1-T4)
1040 P3=T3^(1/G2)
1050 Y1=1-T3
1060 M1=(2/(G1-1))*(Y1/(1-Y1))
1070 Z1=.1*M1
1080 S1=T3+Z1*Y1
1090 X1=SQRT(1-S1)
1100 X4=X1*COS(A1)
1110 B1=ATN((X1*SIN(A1)-X3)/X4)
1120 X5=X4/COS(B1)
1130 T7=S1+X5^2
1140 T5=S1*(P4/P3)^G2
1150 Y6=T7-T5
1160 M2=(2/(G1-1))*Y6/T5
1170 Z2=.2*M2
1180 S2=T5+Z2*Y6
1190 X6=SQRT(T7-S2)
1200 B2=X4/X6
1210 B2=ATN(SQRT(1-B2^2)/B2)
1220 A2=ATN((X6*SIN(B2)-X3)/X4)
1230 X2=X4/COS(A2)
1240 S3=S2+X2^2
1250 T9=1-S3
1260 N1=T9/(1-T4)
1270 P5=P4*(S3/S2)^(1/G2)
1280 T6=P5^G2
1290 N2=T9/(1-T6)
1300 R1=(S1-S2)/(1-S3)

```

Figure D10 (cont) TPL Program: R\_4431T

```
1310 M3=X1*G3
1320 M4=X2*G3*SQRT(1/S3)
1330 M5=X3*G3*SQRT(1/T7)
1340 M6=X6*G3*SQRT(1/T7)
1350 RETURN
1360 DISP "Press F2 to exit, press F3 for another run"
1370 PAUSE
1380 LOAD "DESIGN_MENU",10
1390 END
```

Figure D10 (cont) TPL Program: R\_4431T

```

10  !Title:  TURB3
20  !Author:  R. P. Shreeve (09/01/88)
30  !Updated:  R. Wendland, LCDR, USN (12/12/91)
40  !Program:  Calculate and draw turbine blade profiles.
50  !
60  DEG
70  DUMP DEVICE IS 711
80  CLEAR SCREEN
90  KEY LABELS OFF
100 !----- Input Graph parameters -----
110 INPUT "Plotting STATOR or ROTOR? (stator=0, rotor=1): ",Type
120 IF Type=1 THEN
130   TypeS="ROTOR"
140 ELSE
150   TypeS="STATOR"
160 END IF
170 PRINT "Input axis coordinates for ";TypeS;" blade profile plot:"
180 IF Type=0 THEN
190   INPUT "Enter Xa (nominal -1.0): ",Xa
200   INPUT "Enter Xb (nominal 3.0): ",Xb
210   Type=1
220 ELSE
230   INPUT "Enter Xa (nominal 3.0): ",Xa
240   INPUT "Enter Xb (nominal -1.0): ",Xb
250   Type=-1
260 END IF
270 Ya=-.2
280 Yb=ABS(Xa-Xb)/RATIO+Ya
290 PRINT
300 PRINT "Axis coordinates:"
310 PRINT " Xa = ",Xa
320 PRINT " Xb = ",Xb
330 PRINT " Ya = ",Ya
340 PRINT " Yb = ",Yb
350 PRINT
360 !----- Input Data -----
370 PRINT "Enter all angles in degrees."
380 INPUT "Enter T.E. wedge angle (epsilon): ",E1
390 INPUT "Enter T.E. radius /spacing: ",R8
400 INPUT "Enter output relative flow angle (alpha2 or beta2): ",B3
410 B3=B3*Type
420 !----- EQ. 28 -----
430 A5=COS(B3)-8*R8*(1-B3/90)
440 A0=COS(B3)-8*R8*(1-ATN(SQR(1-A5^2))/A5)/90)
450 IF ABS(A0-A5)<.00001 THEN 480
460 A5=A0
470 GOTO 440
480 INPUT "Enter inlet rel. flow angle(alpha1 or beta1): ",B2
490 B2=-B2*Type
500 INPUT "Enter L.E. radius /spacing (le/S): ",R9
510 INPUT "Enter L.E. wedge angle (delta): ",D1
520 INPUT "Enter axial chord/spacing: ",B0
530 Z0=2*(TAN(B3)+TAN(B2))*COS(B3)^2/B0
540 S0=1
550 B1=B2-10
560 IF D1>20 THEN 580
570 B1=B2-D1/2
580 G1=B1+D1
590 A9=(A0+2*R8)/S0
600 E2=E1/2
610 A8=A9/((1+TAN(E2)^2)
620 A8=A8-SQR(A8^2-(A9^2-TAN(E2)^2)/((1+TAN(E2)^2))
630 A1=ATN(A8/SQR(1-A8^2))
640 R1=(B0-R8*(1+COS(A1+E1)))-R9*(1+SIN(B1))/(COS(A1+E1)+SIN(B1))
650 R2=S0*COS(A1+E1)/SIN(E1)+R8

```

Figure D11 TPL Program: TURB3

```

660 E0=1/(1+SIN(G1-A1-E1))
670 F0=(SIN(G1-A1-E1)+COS(D1))/(1+SIN(G1-A1-E1))
680 G0=(2*(COS(D1/2))^2)/(1+SIN(G1-A1-E1))
690 R3=A0*E0*(COS(G1)*(SIN(A1+E1)-S0/A0)-SIN(G1)*COS(A1+E1))+R1*F0+R9*G0
700 !----- PRINT DATA -----
710 PRINTER IS 711
720 PRINT
730 PRINT "          Turbine Blade Profile"
740 PRINT "          -----"
750 PRINT
760 PRINT "For Axial Chord = ";B0
770 PRINT " Blade Spacing = ";S0
780 PRINT " Exit Width = ";A0
790 PRINT " L.E. Radius = ";R9
800 PRINT " T.E. Radius = ";R8
810 PRINT " L.E. Wedge Angle= ";D1
820 PRINT " T.E. Wedge Angle= ";E1
830 PRINT
840 PRINT "Design Rel. Inlet Flow Angle = ";-B2*Type
850 PRINT "Design Rel. Outlet Flow Angle = ";B3*Type
860 PRINT "Zweifel Coefficient = ";Z0
870 PRINT
880 PRINT
890 PRINT "Calculated Blade Parameters:"
900 PRINT "-----"
910 PRINT " Alpha = ";A1
920 PRINT " Beta = ";B1
930 PRINT " Gamma = ";G1
940 PRINT
950 PRINT " R1 = ";R1
960 PRINT " R2 = ";R2
970 PRINT " R3 = ";R3
980 PRINT
990 PRINT
1000 PRINTER IS CRT
1010 DISP "Press F2 to view plot, F3 for new inputs and recalculate values."
1020 PAUSE
1030 CLEAR SCREEN
1040 !----- Calculate and Plot data to CRT screen -----
1050 ! Graph parameters:
1060 X_range=Xb-Xa
1070 Y_range=Yb-Ya
1080 Dx=10
1090 Dy=10
1100 GINIT
1110 PEN 4
1120 LOG 6
1130 MOVE 100*RATIO/2,100
1140 LABEL Type$;" Blade Profiles"
1150 CSIZE 3.5
1160 MOVE 100*RATIO/2,0
1170 LOG 4
1180 LABEL "Meridian Plane"
1190 LDIR 90
1200 LOG 6
1210 MOVE 0,50
1220 LABEL "Chord"
1230 LDIR 0
1240 LOG 2
1250 VIEWPORT 10,95*RATIO,10,95
1260 FRAME
1270 WINDOW Xa,Xb,Ya,Yb
1280 AXES X_range/Dx,Y_range/Dy,Xa,Ya
1290 AXES X_range/Dx,Y_range/Dy,Xb,Yb
1300 CLIP OFF

```

Figure D11 (cont) TPL Program: TURB3

```

1310 CSIZE 3.0,.4
1320 LORG 6
1330 FOR I=Xa TO Xb STEP X_range/Dy
1340 MOVE I,Ya-.01*Y_range
1350 LABEL USING "#,MD.DD";I
1360 NEXT I
1370 LORG 8
1380 FOR I=Ya TO Yb STEP Y_range/Dy
1390 MOVE Xa-.01*X_range,I
1400 LABEL USING "#,MD.DD";I
1410 NEXT I
1420 K1=0
1430 !----- Trailing Edge -----
1440 T2=-A1
1450 T3=180-A1-E1
1460 T4=(T3-T2)/20
1470 FOR T1=T2 TO T3 STEP T4
1480 X=-R8*SIN(T1)
1490 Y=R8*(1-COS(T1))
1500 PLOT X,Y
1510 NEXT T1
1520 !----- Pressure Side -----
1530 X1=-(R1+R8)*SIN(A1+E1)
1540 Y1=R8+(R1+R8)*COS(A1+E1)
1550 T2=-90+A1+E1
1560 T3=B1
1570 T4=(T3-T2)/20
1580 FOR T1=T2 TO T3 STEP T4
1590 X=X1+R1*COS(T1)
1600 Y=Y1+R1*SIN(T1)
1610 PLOT X,Y
1620 NEXT T1
1630 !----- Tip Radius -----
1640 X4=X1+(R1+R9)*COS(B1)
1650 Y4=Y1+(R1+R9)*SIN(B1)
1660 T2=-B1
1670 T3=180-G1
1680 T4=(T3-T2)/20
1690 FOR T1=T2 TO T3 STEP T4
1700 X=X4+R9*COS(T1)
1710 Y=Y4+R9*SIN(T1)
1720 PLOT X,Y
1730 NEXT T1
1740 X6=X
1750 Y6=Y
1760 PENUP
1770 !----- Suction Side -----
1780 PEN 4
1790 X2=-(R2-R8)*SIN(A1)
1800 Y2=R8+(R2-R8)*COS(A1)
1810 T2=0
1820 T3=E1
1830 T4=(T3-T2)/20
1840 FOR T1=T2 TO T3 STEP T4
1850 X=X2+R2*SIN(T1+A1)
1860 Y=Y2-R2*COS(T1+A1)
1870 PLOT X,Y
1880 NEXT T1
1890 !----- Suction Side Radius R3 -----
1900 X5=X2+R2*SIN(E1+A1)
1910 Y5=Y2-R2*COS(E1+A1)
1920 X3=X5-R3*SIN(E1+A1)
1930 Y3=Y5+R3*COS(E1+A1)
1940 T2=-(90-A1-E1)
1950 T3=G1

```

Figure D11 (cont) TPL Program: TURB3



```

1960 T4=(T3-T2)/20
1970 FOR T1=T2 TO T3 STEP T4
1980 X=X3+R3*COS(T1)
1990 Y=Y3+R3*SIN(T1)
2000 IF Y<Y6 THEN 2060
2010 PENUP
2020 PRINT
2030 PRINT "These values give discontinuous slope on suction side"
2040 PRINT
2050 GOTO 370
2060 PLOT X,Y
2070 NEXT T1
2080 PLOT X6,Y6
2090 PENUP
2100 IF K1=1 THEN 2140
2110 K1=1
2120 WINDOW Xa-S0,Xb-S0,Ya,Yb
2130 GOTO 1430
2140 !----- Area Progression Thru Passage -----
2150 WINDOW Xa,Xb,Ya,Yb
2160 X7=A1+S0
2170 Y7=Y1
2180 T2=-(90-A1-E1)
2190 T3=B1
2200 T4=(T3-T2)/20
2210 PEN 7
2220 LINE TYPE 5
2230 FOR T1=T2 TO T3 STEP T4*2
2240 X=X7+(R1-A0)*COS(T1)
2250 Y=Y7+(R1-A0)*SIN(T1)
2260 PLOT X,Y
2270 NEXT T1
2280 DUMP GRAPHICS
2290 DISP "F2 to continue "
2300 PAUSE
2310 CLEAR SCREEN
2320 INPUT "Calculate blade number? (1=Yes, 0=No): ",N0
2330 IF N0=0 THEN 2470
2340 PRINTER IS 711
2350 INPUT "Enter axial chord (in.): ",B
2360 INPUT "Enter mean radius (in.): ",R5
2370 S=b/B0
2380 Z1=2*PI*R5/S
2390 B=B0*S
2400 A=A0*S
2410 PRINT
2420 PRINT "Axial chord      = ";B;" in."
2430 PRINT "Blade space       = ";S;" in."
2440 PRINT "Throat width      = ";A;" in."
2450 PRINT "Number of blades = ";Z1
2460 PRINTER IS CRT
2470 DISP "F2 to exit, F3 for another run"
2480 PAUSE
2490 LOAD "DESIGN_MENU",10
2500 END

```

Figure D11 (cont) TPL Program: TURB3

```

10  ! Title:  TURB4
20  ! Author:  R. P. Shreeve (09/01/88)
30  ! Updated:  R. A. Wendland, LCDR, USN, (12/17/91)
40  ! Program:  Calculate blade height and lossess for given mean
50  !            line conditions for a single stage axial turbine
60  !
70  DIM O(3,17)
80  CLEAR SCREEN
90  PRINTER IS CRT
100 DUMP DEVICE IS 711
110 KEY LABELS OFF
120 !----- Design Input Data -----
130 PRINT "Input data from program 4431T:"
140 INPUT "Enter Pt0 (psia): ",P0
150 INPUT "Enter Tt0 (deg R): ",T0
160 INPUT "Enter delta Tw (DELTW deg R): ",J0
170 INPUT "Enter w dot (lbs/sec): ",W0
180 !----- Gas Properties -----
190 R4=53.393
200 G9=1.4
210 C9=.24
220 J9=778
230 G8=32.174
240 !----- Velocity Diagram Data -----
250 DEG
260 INPUT "Enter Alpha_e (deg): ",L3
270 INPUT "Enter delta alpha (deg): ",L4
280 INPUT "Enter Micr: ",M1
290 INPUT "Enter Beta_e (deg): ",B3
300 INPUT "Enter delta beta (deg): ",B4
310 INPUT "Enter M'cr1: ",M3
320 INPUT "Enter M'cr2: ",M4
330 !----- Stator Blade Data -----
340 CLEAR SCREEN
350 PRINT "Input STATOR blade data from TURB3:"
360 INPUT "Enter number of blades (z): ",Z1
370 INPUT "Enter throat width (a): ",A
380 INPUT "Enter axial chord (b): ",B
390 INPUT "Enter blade spacing (S): ",S
400 INPUT "Enter blade chord (c): ",C
410 INPUT "Enter trailing edge thickness (ts): ",T7
420 INPUT "Enter maximum blade thickness (tmax): ",T8
430 INPUT "Enter tip clearance (delta t): ",T9
440 !----- Analysis of the Stator -----
450 K=1
460 CLEAR SCREEN
470 INPUT "Enter STATOR profile loss (fig 15 (ref: 1174VA1)): ",S1
480 S9=2*S1
490 N0=1
500 X8=M1^2*(G9-1)/(G9+1)
510 X9=X8/(1-S9)
520 R0=P0*144/(R4*T0)
530 V0=SQR(2*C9*T0*G8*J9)
540 P5=(1-X9)^(G9/(G9-1))
550 T5=1-X8
560 T1=T5*T0
570 P1=P5*P0
580 R1=R0*P5/T5
590 !--- Re into stator
600 X8=X8*(COS(L3)/COS(L3-L4))^2
610 T=1-X8
620 P=T^(G9/(G9-1))
630 R=R0*P/T
640 J1=T*T0
650 M8=1.153E-5*.06333*SQR(J1)/((198.72/J1+1)

```

Figure D12 TPL Program: TURB4

```

660 R9=SQR(X6)*V0*R*C/(M8*12)
670 Q8=R0*V0*SQR(X9)*(1-X9)^(1/(G9-1))
680 D8=L4
690 D7=L3
700 M=SQR((2/(G9-1))*X8/(1-X8))
710 PRINT
720 PRINT
730 PRINT "STATOR Blade Analysis:"
740 PRINT "-----"
750 PRINT
760 GOSUB Blading_loss
770 IF ABS(S9-S6)<.002 THEN 840
780 PRINT "Above results are for iteration ";N0
790 S9=S6
800 N0=N0+1
810 GOTO 510
820 PRINT
830 PRINT
840 PRINT " Blade height = ";H9;" in."
850 PRINT " Exit press. = ";P1;" psia"
860 PRINT " Exit temp. = ";T1;" deg R"
870 PRINT
880 PRINT
890 PRINT
900 O(K,16)=P1
910 O(K,17)=T1
920 DISP "F2 to continue"
930 PAUSE
940 !----- Rotor Blade Data -----
950 K=2
960 PRINT "Input ROTOR blade data from TURB3:"
970 INPUT "Enter number of blades (z): ",Z1
980 INPUT "Enter throat width (a): ",A
990 INPUT "Enter axial chord (b): ",B
1000 INPUT "Enter blade spacing (S): ",S
1010 INPUT "Enter blade chord (c): ",C
1020 INPUT "Enter trailing edge thickness (ts): ",T7
1030 INPUT "Enter maximum blade thickness (tmax): ",T8
1040 INPUT "Enter tip clearance (delta t): ",T9
1050 INPUT "Enter ROTOR profile loss (fig 15, ref: 1174VA1): ",S1
1060 S9=3*S1
1070 N0=1
1080 G7=(G9-1)/(G9+1)
1090 Y8=M4^2*G7
1100 Y9=Y8/(1-S9)
1110 T4=(1-G7*M1^2)/(1-G7*M3^2)
1120 P4=(T4/T5)^(G9/(G9-1))
1130 R3=P4*P5*R0/T4
1140 W3=V0*SQR(T4)
1150 P6=(1-Y9)^(G9/(G9-1))
1160 T6=1-Y8
1170 P2=P6*P4*P1
1180 T2=T6*T4*T0
1190 !----- Re into ROTOR
1200 M8=1.153E-5*.06333*SQR(T1)/(198.72/T1+1)
1210 Y7=M3^2*G7
1220 R9=SQR(Y7)*W3*R1*C/(M8*12)
1230 Q8=R3*W3*SQR(Y9)*(1-Y9)^(1/(G9-1))
1240 D8=B4
1250 D7=B3
1260 M=SQR((T4/T5-1)*2/(G9-1))
1270 PRINT
1280 PRINT
1290 PRINT "ROTOR Blade Analysis:"
1300 PRINT "-----"

```

Figure D12 (cont) TPL Program: TURB4

```

1310 PRINT
1320 GOSUB Blading_loss
1330 IF ABS(S9-S6)<.002 THEN 1380
1340 PRINT "Above results are iteration ";N0
1350 S9=S6
1360 N0=N0+1
1370 GOTO 1100
1380 PRINT
1390 PRINT
1400 PRINT "    Blade height = ";H9;" in."
1410 PRINT "    Exit press.  = ";P2;" psia"
1420 PRINT "    Exit temp.   = ";T2;" deg R"
1430 PRINT
1440 PRINT
1450 PRINT
1460 O(K,16)=P2
1470 O(K,17)=T2
1480 DISP "F2 to continue"
1490 PAUSE
1500 !----- Calculate Stage Performance -----
1510 K=3
1520 P8=P0/P2
1530 P9=P2*((T0-J0)/T2)^((G9/(G9-1)))
1540 P9=P0/P9
1550 E8=T0*(1-(1/P8)^((G9-1)/G9))
1560 E8=J0/E8
1570 E9=T0*(1-(1/P9)^((G9-1)/G9))
1580 E9=J0/E9
1590 PRINT
1600 PRINT "Stage Performance:"
1610 PRINT "-----"
1620 PRINT
1630 PRINT "    Pressure Ratio (T-S) = ";P8;"    Efficiency (T-S) = ";E8
1640 PRINT "    Pressure Ratio (T-T) = ";P9;"    Efficiency (T-T) = ";E9
1650 PRINT
1660 PRINT
1670 O(K,1)=P8
1680 O(K,2)=E8
1690 O(K,3)=P9
1700 O(K,4)=E9
1710 !----- Print Results -----
1720 PRINT "Data to be printed on Printer."
1730 PRINT "--- Ensure paper is correctly set, press F2 to continue."
1740 PAUSE
1750 PRINTER IS 711
1760 PRINT
1770 PRINT
1780 PRINT TAB(27);"Single Stage Axial Turbine Design"
1790 PRINT TAB(27);"-----"
1800 PRINT
1810 PRINT
1820 PRINT TAB(41);"Stator";TAB(61);"Rotor"
1830 PRINT TAB(41);"-----";TAB(61);"-----"
1840 PRINT
1850 PRINT USING "15X,K,11X,5D,15X,5D";"No. of Blades";O(1,8);O(2,8)
1860 PRINT USING "15X,K";"-----"
1870 PRINT
1880 PRINT
1890 PRINT TAB(16);"Blade geometry (inches)"
1900 PRINT TAB(16);"-----"
1910 PRINT
1920 Format1: IMAGE 15X,K,5X,D.3D,14X,D.3D
1930 PRINT USING Format1;"Blade Height"      ",O(1,7),O(2,7)
1940 PRINT USING Format1;"Exit Width"        ",O(1,9),O(2,9)
1950 PRINT USING Format1;"Axial Chord"       ",O(1,10),O(2,10)

```

Figure D12 (cont) TPL Program: TURB4

```

1960 PRINT USING Format1;"Spacing"           ",O(1,11),O(2,11)
1970 PRINT USING Format1;"Chord"             ",O(1,12),O(2,12)
1980 PRINT USING Format1;"T.E. Thickness"    ",O(1,13),O(2,13)
1990 PRINT USING Format1;"Max. Thickness"    ",O(1,14),O(2,14)
2000 PRINT USING Format1;"Tip Clearance"      ",O(1,15),O(2,15)
2010 PRINT
2020 PRINT
2030 Format2: IMAGE 15X,K,5X,D.4D,13X,D.4D
2040 PRINT TAB(16);"Blade Row Performance"
2050 PRINT TAB(16);"-----"
2060 PRINT USING Format2;"Ref. Profile Loss"  ",O(1,1),O(2,1)
2070 PRINT USING Format2;"Tot. Profile Loss"  ",O(1,2),O(2,2)
2080 PRINT USING Format2;"Sec. Flow Loss"     ",O(1,3),O(2,3)
2090 PRINT USING Format2;"Mixing Loss"        ",O(1,4),O(2,4)
2100 PRINT USING Format2;"Tip Clearance Loss" ",O(1,5),O(2,5)
2110 PRINT USING Format2;"Total Loss Coeff."  ",O(1,6),O(2,6)
2120 PRINT
2130 Format3: IMAGE 15X,K,5X,3D.2D,14X,3D.2D
2140 PRINT USING Format3;"Exit Pressure (psia)",O(1,16),O(2,16)
2150 PRINT USING Format3;"Exit Temp. (deg R)",O(1,17),O(2,17)
2160 PRINT
2170 PRINT
2180 PRINT TAB(16);"Stage Performance";TAB(39);"Total-Total";TAB(59);"Tot-Static"
2190 PRINT TAB(16);"-----";TAB(39);"-----";TAB(59);"-----"
2200 PRINT
2210 PRINT USING Format1;"Pressure Ratio"      ";O(3,3),O(3,1)
2220 PRINT USING Format2;"Efficiency"          ";O(3,4),O(3,2)
2230 PRINTER IS CRT
2240 GOTO 2740
2250 !----- Blading loss subroutine -----
2260 Blading_loss: !
2270 !----- Total Profile Loss -----
2280 PRINT "Re = ";R9
2290 INPUT "Enter K(Re) (fig 23, ref: GA1074VA2): ",K1
2300 PRINT "Mach# = ";M
2310 INPUT "Enter K(M) (fig 18, ref: 1174VA1): ",K3
2320 K2=1+2*(T8/C-.2)
2330 S2=S1*K1*K2*K3
2340 W9=W0*144/(Z1*Q8*A^2)
2350 H9=A*(W9*(1+.77*S2)+.025*S2*D8)
2360 !----- Secondary Flow Loss -----
2370 H5=(S-T7)*COS(D7)/H9
2380 S3=S2*.0323*D8*H5*(1+.962*S2)/(1-.03*D8*H5*S2)
2390 !----- Mixing Loss -----
2400 S4=(T7/S+.962*S2)/(1+.962*S2)
2410 S4=(COS(D7)*S4/(1-S4))^2
2420 S4=S4/(1+S4)
2430 !----- Tip Clearance Loss -----
2440 D6=D7-D8
2450 D5=ATN((TAN(D6)+TAN(D7))/2)
2460 S5=COS(D7)^2*(ABS(TAN(D6)-TAN(D7))^1.5/COS(D5))
2470 S5=2.26*S5*T9/(H9*SQR(B/S))
2480 S5=S5/(1+S5)
2490 !----- Total Losses -----
2500 S6=S2+S3+S4+S5
2510 PRINT "Ref. Profile Loss = ";S1
2520 PRINT "Tot. Profile Loss = ";S2
2530 PRINT "Sec. Flow Loss = ";S3
2540 PRINT "Mixing Loss = ";S4
2550 PRINT "Tip Clearance Loss = ";S5
2560 PRINT
2570 PRINT " Total Loss = ";S6
2580 O(K,1)=S1
2590 O(K,2)=S2
2600 O(K,3)=S3

```

Figure D12 (cont) TPL Program: TURB4

```
2610 O(K,4)=S4
2620 O(K,5)=S5
2630 O(K,6)=S6
2640 O(K,7)=H9
2650 O(K,8)=Z1
2660 O(K,9)=A
2670 O(K,10)=B
2680 O(K,11)=S
2690 O(K,12)=C
2700 O(K,13)=T7
2710 O(K,14)=T8
2720 O(K,15)=T9
2730 RETURN
2740 DISP "F2 to exit, F3 for another run"
2750 PAUSE
2760 PRINTER IS CRT
2770 LOAD "DESIGN_MENU",10
2780 END
```

Figure D12 (cont) TPL Program: TURB4

```

10  !Program: DESIGN_MENU
20  !Description: Program to provide Function Key menu selection of programs.
30  !
40  CLEAR SCREEN
50  PRINTER IS CRT
60  KEY LABELS ON
70  ON KEY 1 LABEL "R_4431T" GOTO R_4431t
80  ON KEY 2 LABEL "A_4431T" GOTO A_4431t
90  ON KEY 3 LABEL "TURB3" GOTO Turb3
100 ON KEY 4 LABEL "TURB4" GOTO Turb4
110 ON KEY 5 LABEL " " GOTO Hold
120 ON KEY 6 LABEL " " GOTO Hold
130 ON KEY 7 LABEL "MAIN MENU" GOTO Main
140 ON KEY 8 LABEL "EXIT MENU" GOTO Exit
150 !
160 PRINT "Turbo-propulsion Design Programs"
170 PRINT
180 PRINT "Item:                               Select Function Key"
190 PRINT
200 PRINT "  R_4431T: Performanc Calculations      F1"
210 PRINT "              (Iterate on R*)"
220 PRINT "  A_4431T: Performanc Calculations      F2"
230 PRINT "              (Iterate on Alpha)"
240 PRINT "  TURB3: Draw Blade Profiles          F3"
250 PRINT "  TURB4: Blade Height and Loses      F4"
260 PRINT
270 PRINT "  Main Menu                          F7"
280 PRINT "  Exit Menu                          F8"
290 !
300 Hold: !
310 GOTO Hold
320 R_4431t: !
330 LOAD "R_4431T",10
340 A_4431t: !
350 LOAD "A_4431T",10
360 Turb3: !
370 LOAD "TURB3",10
380 Turb4: !
390 LOAD "TURB4",10
400 Main: !
410 MASS STORAGE IS "/WORKSTATIONS"
420 LOAD "AUTOST",10
430 Exit: CLEAR SCREEN
440 END

```

Figure D13 TPL Program: DESIGN\_MENU

```

1      !Program: SCAN
10     !Descrip: Reads voltages from designated scanivalve through scanner #1
20     !          and prints to CRT port # and voltages in pressure (in. Hg).
30     !Devices: HP3495A(701) #1, HP3456A(722), HG-78(707), Scanivalve(1-5)
40     !Modify: Using Molye routines.
50     !Notes:   Devices HP3495A and HG-78 use specific communication formats
60     !          in the OUTPUT statements by utilizing the image form USING.
70     !
80     !          HP3495A: OUTPUT 701 USING "DDD";V+9
90     !          HG-78:  OUTPUT 707 USING "#,K";V
100    !
110    DIM Press(1:50)                !Assign array in Memory.
120    !Designate Scanivalve:
130    INPUT "Input Scanivalve, First port, Last port:",V,First,Last
140    !
150    OUTPUT 722;"6STG10STIT3"        !Set-up HP3456A DVM.
160    CLEAR 701                      !Reset HP3495A Scanner.
170    !
180    FOR Port_reqd=First TO Last      !Routine to read pressure values.
190        GOSUB Read                  !Subroutine to read Scanivalve
200        WAIT .5                     !port number from HG-78.
210        OUTPUT 701 USING "DDD";V+9  !Set Scanner connect DVM to HG-78
220        TRIGGER 722                 !Trigger DVM to read Scanivalve.
230        ENTER 722;Press(Port_reqd) !DVM reads value, and writes to
240        CLEAR 701                   !HP9000 memory. Scanner is reset.
250    NEXT Port_reqd
260    CLEAR 722                      !Reset DVM.
270    !
280    PRINT "PORT #","PRESS (IN. H2O)" !Routine to print results to the
290    PRINT                           !HP9000 CRT.
300    FOR I=First TO Last
310        PRINT I,Press(I)*100000
320    NEXT I
330    !
340    GOTO Finish
350    !*****END OF MAIN PROGRAM*****
360    !
370    !*****SUBROUTINE READ AND POSITION SCANIVALVE *****
380    Read: !
390    OUTPUT 707 USING "#,K";V        !Routine to call HG-78, ask for the
400    P0=SPOLL(707)                  !current port assigned, read the port
410    L=BINAND(P0,15)                 !number, and convert it to decimal
420    T=SHIFT(P0,4)                   !format.
430    M=BINAND(T,7)
440    Port_read=10*M+L                !Scanivalve port number in decimal
450    CLEAR 707                      !format.
460    IF Port_read=Port_reqd THEN Exit !Exit subroutine if reqd port selected
470    OUTPUT 701 USING "DDD";V-1      !Advance S/V to next port
480    CLEAR 701                      !Reset Scanner
490    WAIT .1
500    GOTO Read                      !Loop to Read for another port reading.
510    Exit:RETURN
520    !*****END OF SUBROUTINES*****
530    Finish:
540    END

```

Figure D14 TPL Program: SCAN



```

10  SUB Plot
20  ! Subroutine to display plot screen, less the plots of any curves
30  ! for the specified variables in the COM /Plot_labels/ line.
40  COM /Plot_labels/ Xo,Xf,Yo,Yf,Dx,Dy,Title$,X_label$,Y_label$
50  CLEAR SCREEN
60  KEY LABELS OFF
70  GINIT                                !Initialize graph routine
80  X_range=Xf-Xo                        !Length of X-axis
90  Y_range=Yf-Yo                        !Length of Y-axis
100 LONG 8                               !Character ref pt:top center
110 MOVE 100*RATIO/2,100                 !Move cursor to screen loc for labels
120 CSIZE 3                              !Size labeling
130 LABEL Title$                         !Plot title
140 MOVE 100*RATIO/2,0                   !Move cursor to bottom center screen
150 LONG 4                               !Character ref pt:bottom center
160 LABEL X_label$                       !X-axis label
170 DEG                                  !Desig degrees for LDIR
180 LDIR 90                              !Sets Y-axis label on end
190 LONG 8
200 MOVE 0,50
210 LABEL Y_label$                       !Y-axis label
220 LDIR 0                               !Reset label to horizontal orientation.
230 LONG 2                               !Chr ref pt:left center
240 VIEWPORT 10,90*RATIO,10,90          !Sets graph screen size
250 FRAME                                !Box around VIEWPORT
260 WINDOW Xo,Xf,Yo,Yf                  !Set axis lengths in VIEWPORT
270 AXES X_range/Dx,Y_range/Dy,Xo,Yo    !Axes intersect at lower left
280 AXES X_range/Dx,Y_range/Dy,Xf,Yf    !Axes intersect at upper right
290 GRID X_range/Dx,Y_range/Dy,Xo,Yo,Dx,Dy,.001 !Create dot grid background
300 CLIP OFF                             !So labels can print outside VIEWPORT
310 CSIZE 3.0,.4                         !Axes label size
320 LONG 8                               !Number X-axis
330 FOR I=Xo TO Xf STEP X_range/Dx
340   MOVE I,Yo-.01*Y_range
350   LABEL USING "#,X";I
360 NEXT I
370 LONG 8                               !Number Y-axis
380 FOR I=Yo TO Yf STEP Y_range/Dy
390   MOVE Xo-.01*X_range,I
400   LABEL USING "#,Y";I
410 NEXT I
420 CLIP ON
430 !
440 SUBEND

```

Figure D15 TPL Subprogram: Plot

```

10  IDate$=FNDate$(TIMEDATE)
20  DEF FNDate$(Seconds)
30    Julian=Seconds DIV 86400-1721119
40    Year=(4*Julian-1) DIV 146097
50    Julian=(4*Julian-1) MOD 146097
60    Day=Julian DIV 4
70    Julian=(4*Day+3) DIV 1461
80    Day=(4*Day+3) MOD 1461
90    Day=(Day+4) DIV 4
100   Month=(5*Day-3) DIV 153 ! Month
110   Day=(5*Day-3) MOD 153
120   Day=(Day+5) DIV 5 ! Day
130   Year=100*Year+Julian
140   IF Month<10 THEN
150     Month=Month+3
160   ELSE
170     Month=Month+3
180     Year=Year+1
190   END IF
200   Year$=VAL$(Year)
210   IF Month<10 THEN
220     Month$="0"&VAL$(Month)
230   ELSE
240     Month$=VAL$(Month)
250   END IF
260   IF Day<10 THEN
270     Day$="0"&VAL$(Day)
280   ELSE
290     Day$=VAL$(Day)
300   END IF
310   DS=Year$(3,4)&Month$&Day$
320   RETURN DS
330  FNEND

```

Figure D16 TPL Subprogram: FNDate\$

```

10  !Program:FILE_XFER
20  !Description: transfers selected files to a selected directory, and
30  !             PURGES the same file if desired.
40  ON ERROR GOTO Error
50  CLEAR SCREEN
60  DIM Directory1$(35)
70  DIM Directory2$(35)
80  PRINT "This program transfers files from an existing specified INITIAL directory"
90  PRINT "to a NEW directory."
100 INPUT "Initial Directory? (ex. '/', '/WORK/')",Directory1$
110 INPUT "New directory? (ex. '/', '/WORK/')",Directory2$
120 CLEAR SCREEN
130 CAT Directory1$
140 Transfer: !
150 INPUT "File for transfer (CAT to print directory, QUIT to Exit)",File$
160 IF File$="QUIT" THEN Finish
170 IF File$="CAT" THEN
180   CLEAR SCREEN
190   CAT Directory1$
200   GOTO Transfer
210 END IF
220 Copy: !
230 COPY Directory1$&File$ TO Directory2$&File$
240 PRINT "File ";Directory1$&File$;" transferred to ";Directory2$&File$
250 INPUT "Purge this file from current directory? (Yes=1 No=0)",Del
260 IF Del=1 THEN
270   PURGE Directory1$&File$
280 END IF
290 GOTO Transfer
300 Error: !
310 IF ERR=54 THEN
320   PRINT "File: ";Directory2$&File$;" already exist."
330   INPUT "Do you want to purge? (0=No 1=Yes)",File_purge
340   IF File_purge=1 THEN
350     PURGE Directory2$&File$
360     PRINT "File: ";Directory2$&File$;" purged."
370     GOTO Copy
380   ELSE
390     PRINT "File: ";Directory2$&File$;" NOT purged."
400   END IF
410 END IF
420 GOTO Transfer
430 Finish: !
440 CLEAR SCREEN
450 END

```

Figure D17 TPL Program: FILE\_XFER

```
10  !Program: MAIN_MENU returns working window to the Main Menu
20  CONTROL CRT,5;4      !Reset screen color to Green.
30  MASS STORAGE IS "/WORKSTATIONS"
40  LOAD "AUTOST",10
50  END
```

Figure D18 TPL Program: MAIN\_MENU

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